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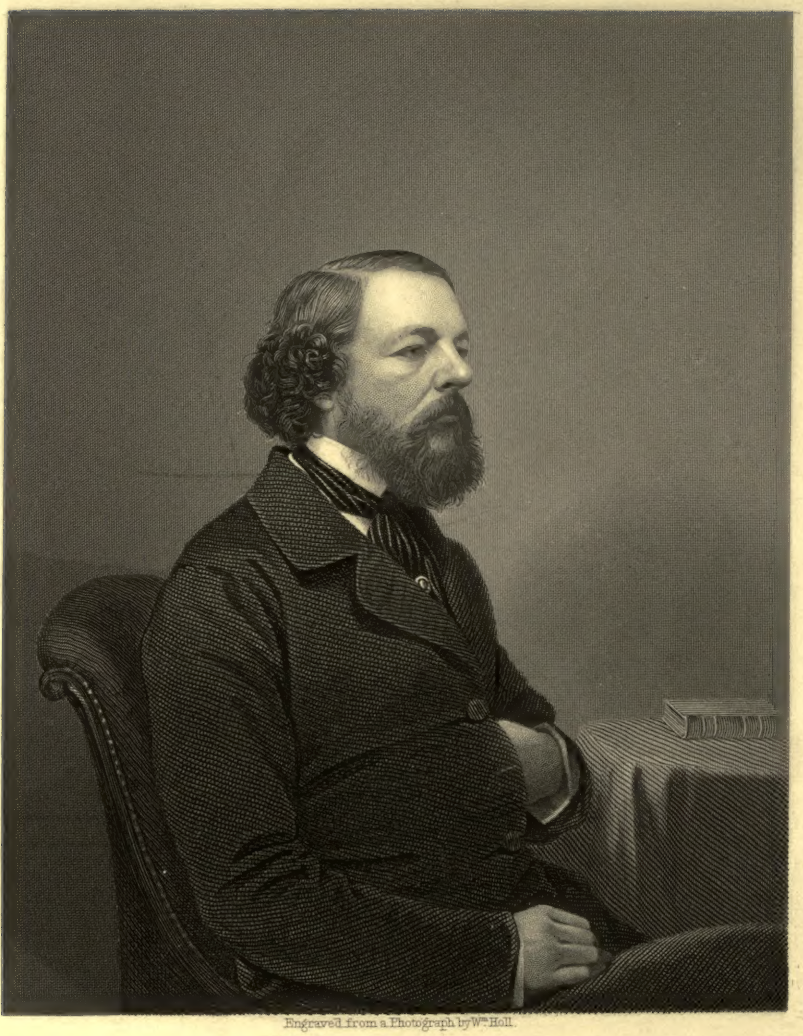

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THEORETICAL, PRACTICAL & ANALYTICAL,

AS APPLIED AND RELATING TO

The Arts and Manufactures.

BY

DR. James SHERIDAN MUSPRATT, F.R.S.E. M.R.I.A. F.G.S.

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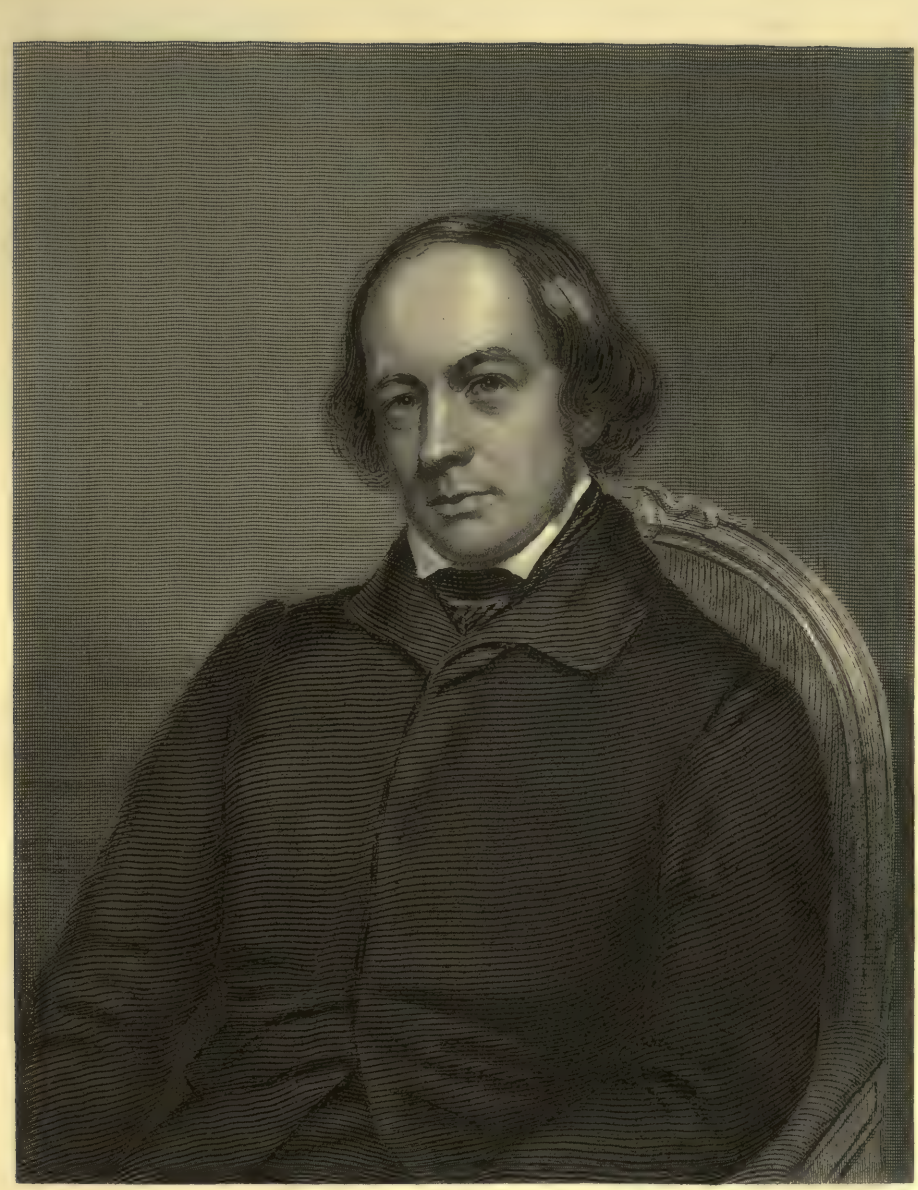

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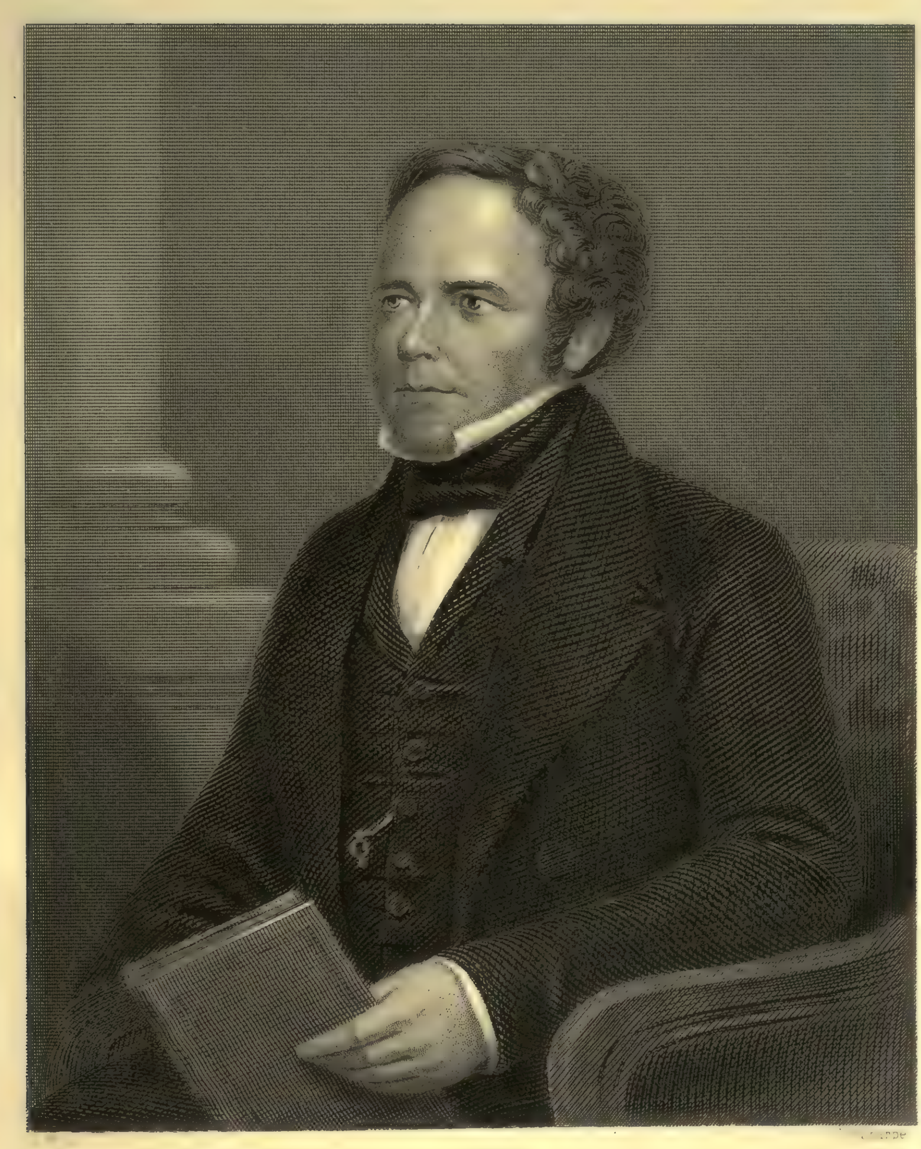

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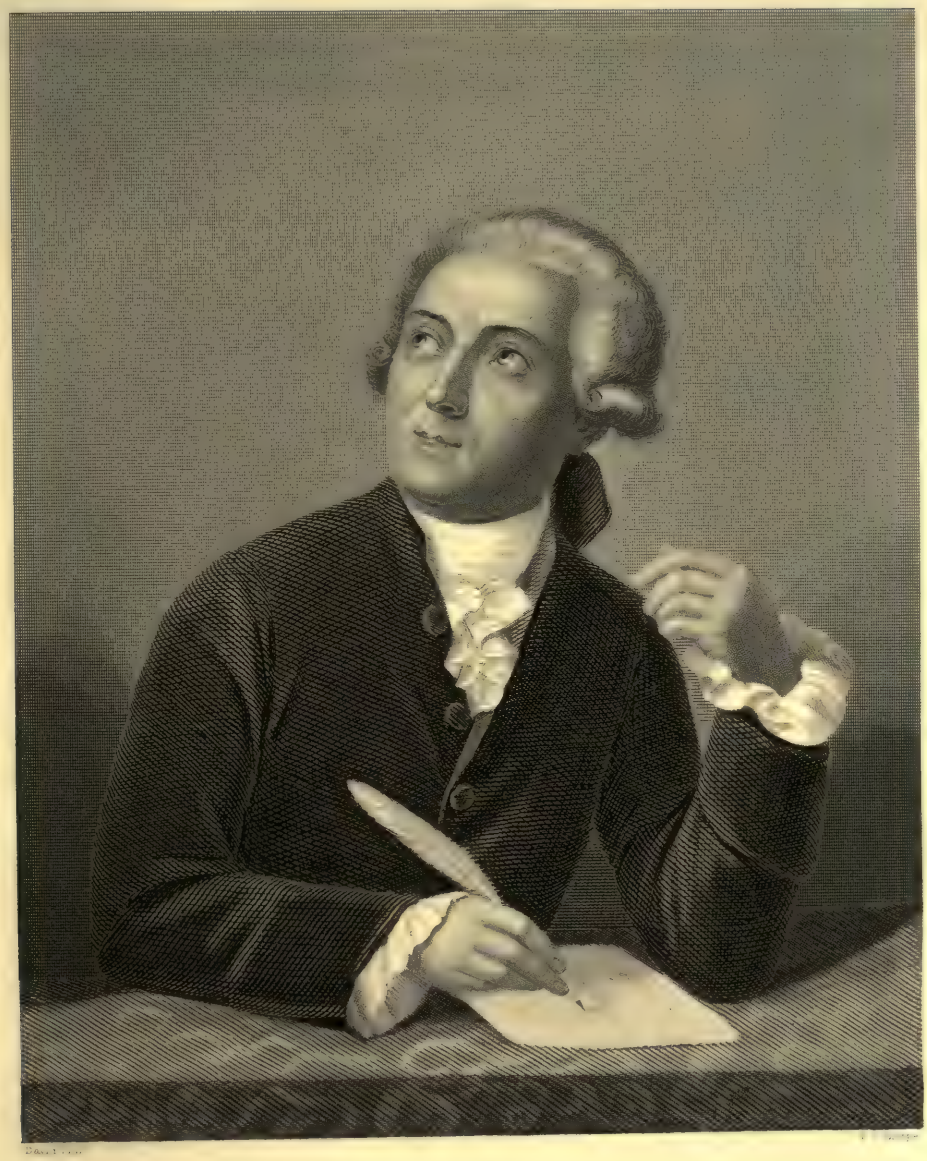

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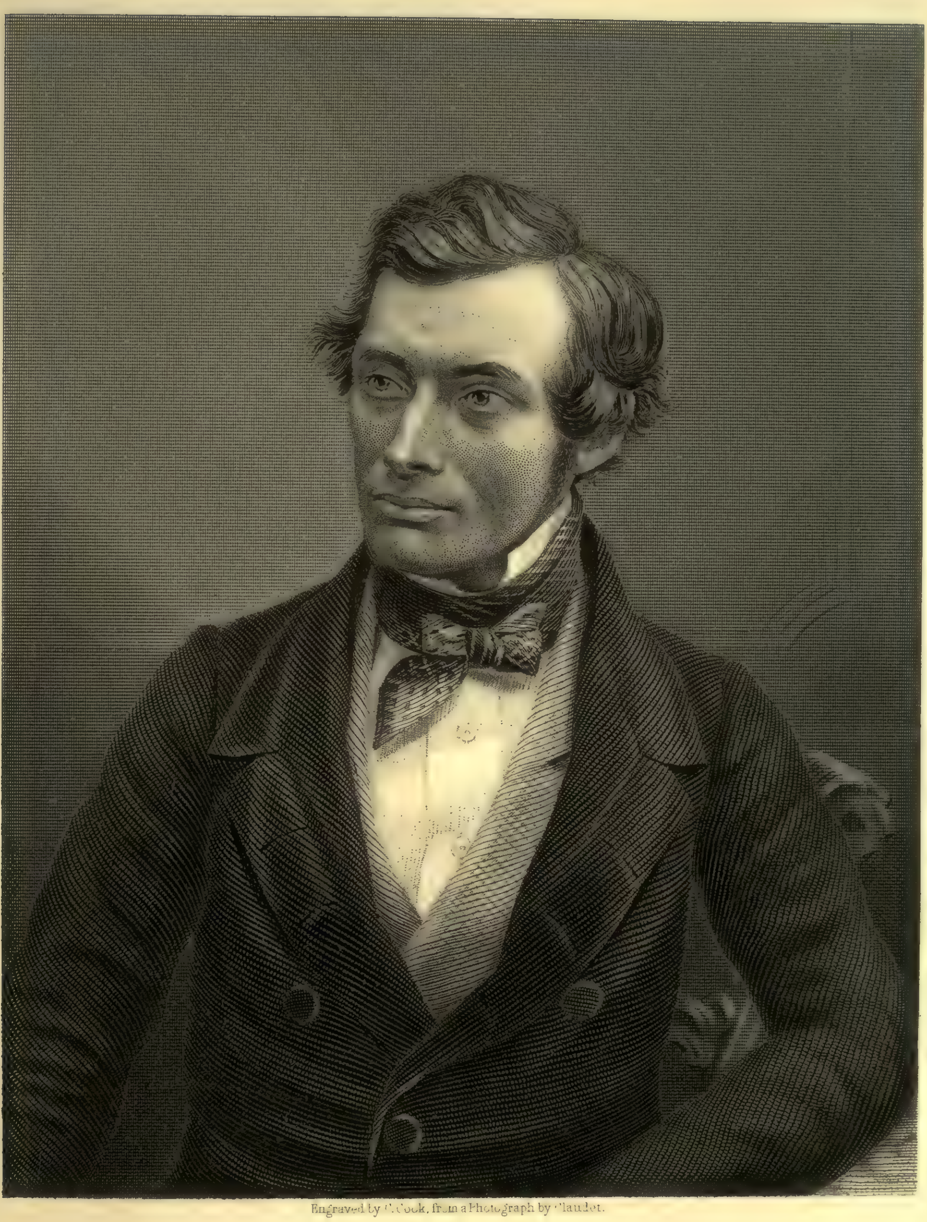

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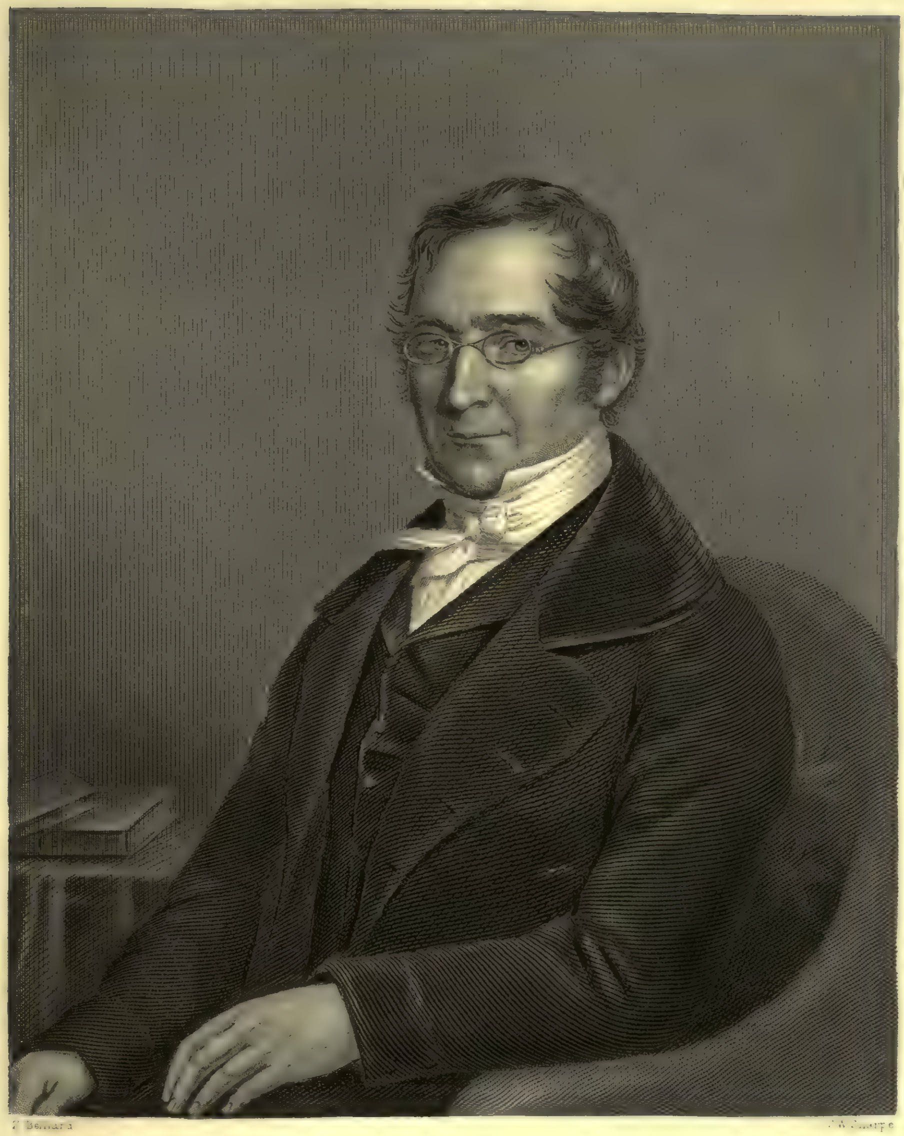

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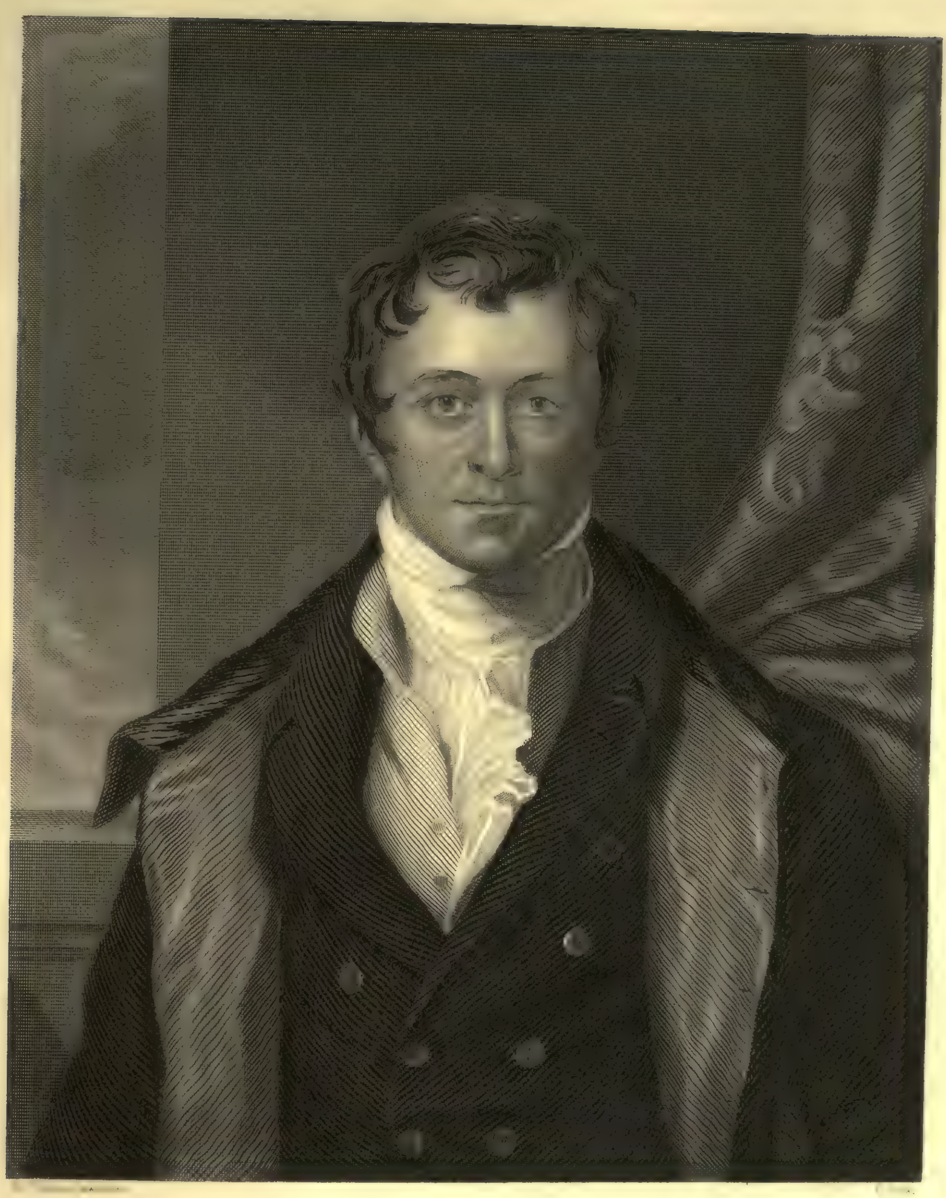

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CHEMISTRY,

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED AND RELATING TO THE

ARTS AND MANUFACTURES.

BY

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PREFACE.

THE Editor, in congratulating himself and his readers that his arduous but not unpleasant labors are at length brought to a close, begs to acknowledge most gratefully the cordial support which he has received from the conductors of the periodical press, and the numerous favorable testimonies, not only from the most eminent scientific men and manufacturing chemists, but also from non-professional readers and subscribers generally, by which he has been sustained and encouraged. It is only those who have been actually engaged in a work of this kind, that are able to conceive the vast amount of labor which it involves, and the difficulty of realizing in detail the ideal standard which an author usually proposes to himself in commencing such an undertaking; especially one that has to extend over a period of several years.

With reference to the present Work, the Editor is well aware that it labors under many imperfections, but he is conscious also that he has spared no pains to render it as extensively useful as possible; and he thinks he may say with entire confidence and without presumption, that in no other work hitherto published will be found so complete an exposition of the state of the chemical manufactures, with the latest and most improved processes. He regrets exceedingly that in aiming to embrace the whole of these, so far as they appeared to him of any practical value, and in wishing to avail himself of the numerous details, articles, *et cetera*, so kindly furnished to him by his valuable and talented assistant, Mr. MURPHY, Mr. GEORGE BLAIR of Glasgow, and other scientific friends, and in many instances by gentlemen immediately engaged in or connected with the different manufactures, he has found it necessary to extend the Work somewhat beyond the limits originally assigned. It may even appear to the general reader that in some cases he has described particular processes with too much minuteness; but those who are really desirous of useful practical information on any of the subjects discussed, will find in this very minuteness of detail the most valuable feature of the Work. Many of the articles might have been considerably extended, but few of them, if any, could have been much abridged, without omitting facts the importance of which the reader will be best able to appreciate when he consults the book for his practical guidance.

SHERIDAN MUSPRATT, M.D., &c.,
PROFESSOR OF CHEMISTRY.

THE HOLLIES,
West Derby, near Liverpool, 1860.

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PRESIDENT OF THE QUEEN'S COLLEGE, CORK; DIRECTOR OF THE MUSEUM OF IRISH INDUSTRY;
&c. &c. &c.

To whom could I with greater propriety inscribe this Work than to my distinguished friends and colleagues; both of whom have contributed the most valuable assistance to the Arts and Manufactures of their respective countries, as well as to the world in general.

Baron DUMAS' Traité de Chimie Appliquée aux Arts, and Sir ROBERT KANE'S Industrial Resources of Ireland, are treatises which, in their completeness as volumes of reference, are unquestionably mines whence much has already been extracted, and through which great advances must still be made in Technology. These works, *per se*, entitle their authors to the most prominent rank.

For repeated acts of disinterested kindness and attention, I shall ever hold myself their debtor; and I rejoice in availing myself of the first opportunity which enables me to record the grateful and sincere acknowledgment.

SHERIDAN MUSPRATT.

ROYAL COLLEGE OF CHEMISTRY,
LIVERPOOL.

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CHEMISTRY,

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED AND RELATING TO

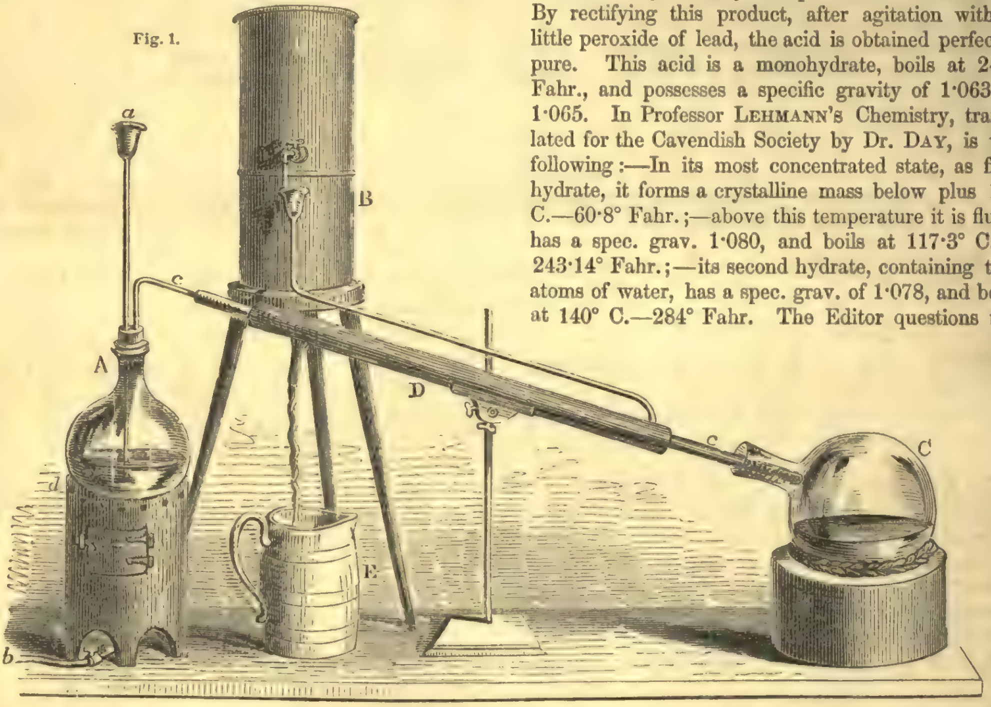
THE ARTS AND MANUFACTURES.

> There are qualities in the products of Nature yet undiscovered, and combinations in the powers of Art yet untried. It is the duty of every man to endeavor that something may be added, by his industry, to the hereditary aggregate of knowledge and happiness.—Dr. Johnson.

ACETIC ACID.

ACETIC ACID—*Acide Acétique*, French; *Essigsaure*, German; *Acidum Aceticum*, Latin; *Eisel*, Saxon—is the name of the acerb principle existing in vinegar. It has been known from time beyond memory, that the expressed juice of fruit, after becoming vinous by a species of fermentation, was, under particular circumstances, found to undergo another change; that is, it became acrid to the taste—a conversion we now call the *acetous fermentation*, and the acid produced, *acetic acid*. Under the name *vinegar*, this acid was known many ages before the discovery of any other, those only excepted which exist ready-formed in the vegetal kingdom. It appears, from the writings of Moses, that it was in very general use among the Israelites, and other Eastern nations, at a very remote period; there existed, however, no definite knowledge with regard to the nature of its formation, and even in the commencement of the eighteenth century, great ignorance was manifested as to the cause of its production. At this early date, when comparatively very little was understood of chemical science, it was impossible to investigate the theory of these changes, owing to the number of substances contained in the liquids, and the great variety of circumstances producing such metamorphoses. With all the advantages which chemistry holds forth, there are many points still remaining to be cleared up in some of the practical details of the *acetous fermentation;* however, we are enabled to lay down one principle as its cause, in all the processes for making acetic acid, with the exception of its formation in the distillation of wood. The alchemists were acquainted with this acid in a concentrated state, as *radical vinegar*, or *vinegar of Venus;* and the product of the rectification of this liquid they named *distilled vinegar*, or *acetous acid*. Berthollet, in 1785, published a paper wherein he endeavored to demonstrate that the acid obtained from the distillation of verdigris—acetate of copper—was different from *acetous acid*, as then known, both in physical characteristics, as well as in its affinity for other bodies, in forming neutral compounds with them. The phlogiston theory being at this time in the ascendant, Berthollet concluded that, during distillation, the acetous acid gave out phlogiston to the copper, and received oxygen in return; hence it was assumed that the new liquid was acetous acid united with oxygen, and was accordingly named *acetic acid*. After the phlogiston theory had exploded, the views of Berthollet were not materially altered on that account, for, the residue in the retort being metallic copper, it was supposed that the acetous acid deprived the oxide of copper of its oxygen. Stahl and Westendorf were the first to prepare the acid in a pure state, but Löwitz was the first to obtain it as a pure hydrate of acetic acid in 1793. Afterwards, it was observed by Dr. J. Davy, that spongy platinum, in contact with the vapor of alcohol, became incandescent, and generated this acid. Döbereiner further studied the nature of the acid, and proved that the alcohol was oxidized at the expense of the atmospheric air, producing acetic acid and water, and that no carbonic acid was formed—thus pointing out the fallacy of the opinion held by the chemists of his time, that carbonic acid was one of the products of the acetous fermentation. Further, he showed that, for the complete oxidation of one atom of alcohol, four atoms of oxygen were required. This acid is produced under various circumstances, and in a variety of ways, some of which are, in a theoretical point of view, extremely important. When alcohol is treated with hot potassa-lime, hydrogen gas is evolved, and acetate of potassa is formed. Cane sugar, on being boiled with a concentrated solution of potassa, eliminates hydrogen, and gives rise to a series of acids, the principal of which are acetic and oxalic. The pure acid is obtained by distilling acetate of soda or potassa with sulphuric acid. Fig. 1 is an apparatus well adapted for this purpose. A is a flask, closed by a cork, which receives two tubes; one of these is a funnel tube, *a*, through which the liquid bodies are introduced, and the other conducts the vapors to the condenser. This consists of an outer case, D, through which the tube, *c c*, connected with the bent tube from the flask, A, passes. The condenser is cooled by keeping a stream of water running constantly from the reservoir, B; C is a flask to receive the condensed vapors; *d* the gas lamp which heats the liquid in A; *b* the gas pipe, and E the vessel into which the heated water flows from the condenser. A convenient quantity, say half a pound, of pure acetate of soda, is introduced into the flask, and about five ounces of strong sulphuric acid, sp. gr. 1·80, poured in through the funnel, *a*, and the whole well agitated. Sufficient heat is developed to cause one-eighth of the acid to distil over without fire, and the heat of the sandbath is sufficient to expel the rest. A colorless liquid is obtained, which has a specific gravity of about 1·061, and contains forty to forty-two per cent. of real acid. By rectifying this product, after agitation with a little peroxide of lead, the acid is obtained perfectly pure. This acid is a monohydrate, boils at 248° Fahr., and possesses a specific gravity of 1·063 to 1·065. In Professor **Lehmann's** Chemistry, translated for the Cavendish Society by Dr. **Day**, is the following:—In its most concentrated state, as first hydrate, it forms a crystalline mass below plus 16° C.—60·8° Fahr.;—above this temperature it is fluid, has a spec. grav. 1·080, and boils at 117·3° C.—243·14° Fahr.;—its second hydrate, containing two atoms of water, has a spec. grav. of 1·078, and boils at 140° C.—284° Fahr. The Editor questions the accuracy of the above. In all other chemical works, the specific gravity of the monohydrated acid is given as 1·063. It is strange that Dr. **Day** should not, in a note, have alluded to this apparent error. The acid with one equivalent of water has the composition—

Fig. 1.



	Atomic Weight.		Centesimal Quantities of each.
4 Eqs. of carbon,	24	=	40
3 Eqs. of hydrogen,	3	=	5
3 Eqs. of oxygen,	24	=	40
1 Eq. of water,	9	=	15
	60		100

Formula, $HO, C_4 H_3 O_3$.

For a long time it baffled the labors of the chemist to obtain the acid *free from water*, every available means applied proving unsuccessful. Lately, however, **Gerhardt** has produced the anhydrous acid, by mixing chloride of benzoyle and fused acetate of potassa in a flask, and allowing them to heat on a sandbath. Chloride of potassium is first formed, and a substance which is probably acetate of benzoyle; but the action does not stop here, since, on heating the mixture above this temperature, with an excess of acetate of potassa, the first-mentioned bodies react upon each other, and there distils a perfectly colorless iridescent liquid, having the unmistakeable odor of acetic acid. This liquid is anhydrous, boils at 279·5° Fahr., is heavier than water, in which it sinks as an oil, and at the temperature of 58° or 60° they are immiscible. Hot water changes it into ordinary acetic acid. The odor of acetic acid is most peculiar—suffocating, but when mixed with air agreeable; it is nearly as acrimonious as sulphuric acid; when dropped on the skin it acts like an escharotic, producing much heat and rapid inflammation of the part with which it is in contact. Cold acetic acid is not inflammable, but when boiled its vapor ignites, burning with a blue flame. It distils without change—even a red heat only slightly decomposes it. When its vapor is passed through tubes containing red-hot charcoal, it suffers decomposition rapidly, giving rise to carbonic acid, carbonic oxide, carbide of hydrogen, and water.

Acetic acid, with most bases, gives salts soluble in water and in alcohol; even acetate of lead is soluble in the latter—a few neutral acetates only are sparingly soluble. A solution of nitrate of silver is not clouded by free acetic acid; but it is troubled by saturating the free acid with ammonia.

Subnitrate of mercury determines at once, in acetic acid, a crystalline precipitate. Acetic acid does not reduce the terchloride of gold, even in the heat; but if an excess of potassa be added, metallic gold is immediately deposited.

Acetates tinge the sesquisalts of iron blood-red. Free acids, except acetic acid, destroy this color. Of all the volatile organic acids, acetic acid is the only one having the property of dissolving protoxide of lead, in the state of a basic acetate, which solution, when the oxide of lead is in excess, has an alkaline reaction on reddened litmus paper—a characteristic test.

The specific gravity of the acid is variable, the monohydrate being 1·063, while the same acid diluted with five atoms of water, or fifty-one and a half per cent., possesses the like specific gravity. Hence, in determining the strength of acetic acid, the density is no criterion of the amount of acetic acid present, as is shown in the subjoined table, drawn up by Thomson:—

Equivalents of Acid.		Equivalents of Water.	Sp. Gr. at 60°.
1	+	1	1·06296
1	+	2	1·07060
1	+	3	1·07084
1	+	4	1·07132
1	+	5	1·06820
1	+	6	1·06708
1	+	7	1·06349
1	+	8	1·05974
1	+	9	1·05794
1	+	10	1·05439

From the following table it will be seen, that when it is required to determine the amount of dry acid in rather dilute solutions, the specific gravity test answers pretty well within certain limits; but when the acid increases in strength, it is evident from the preceding that this test is fallacious, as the acid containing only *one* atom of water, and that with *six* atoms of water to one of acetic acid, are of the same density.

Hydrated Acid in 100 parts.	Sp. Gr.	Hydrated Acid in 100 parts.	Sp. Gr.	Hydrated Acid in 100 parts.	Sp. Gr.
100	1·0635	67	1·0690	34	1·0450
97	1·0680	64	1·0680	31	1·0410
94	1·0706	61	1·0670	28	1·0380
91	1·0721	58	1·0660	25	1·0340
88	1·0730	55	1·0640	22	1·0310
85	1·0730	52	1·0620	19	1·0260
82	1·0730	49	1·0590	16	1·0230
79	1.0735	46	1·0550	13	1·0180
76	1·0730	43	1·0530	10	1·0150
73	1·0720	40	1·0513	7	1·0107
70	1·0700	37	1·0480	4	1·0050

The method for testing the strength of acetic acid, *et cetera*, is fully described under Vinegar, page 32. This acid is without doubt the most interesting of all the organic acids, as it enters more than any other into the industrial arts, and occurs the most frequently in nature, ready formed in several products of the vegetal kingdom. Acetic acid exists in the sap of nearly all plants, and probably in divers liquids dependent on the animal economy; but is never found in any large quantity. Several organic matters give birth to this acid during their decomposition. It is also produced by the putrefaction of animal and vegetal substances; the action of the alkalies, at an elevated temperature, converts some vegetal acids into acetic and oxalic acids—in fact, nearly all the bodies of an organic nature produce acetic acid when submitted to distillation. Besides the processes already glanced at for the production of acetic acid, a variety of others are resorted to for its formation. An interesting method, on account of its beauty and perfection, is the oxidation of alcohol, through the agency of spongy platinum. It is a well-known fact, that spongy platinum—platinum black—from its minute state of division, condenses within its pores several hundred times its volume of atmospheric air; consequently, when the vapor of alcohol comes in contact with this body, a supply of oxygen in a concentrated state is presented to it, and the platinum, without losing any of its inherent properties, effects chemical combination; the alcohol undergoing slow combustion, and being converted into acetic acid. This can be illustrated by an apparatus similar to Fig. 2,—A is a bell glass, through the mouth of which a long funnel, *a*, passes; the lower end of this funnel terminates in a fine point, so that the alcohol poured in may percolate very slowly. The vessel is placed upon supports, *b*, within a dish, B, in which is a saucer or small flat basin, containing the spongy platinum. The interstice from the bottom of the dish, B, and the bell, A, serves for the circulation of air in the jar. On pouring the alcohol through *a*, in the course of a short time the odor of acetic acid is perceived at the mouth, from the acetic acid vapors which are generated. These condense on the sides of the jar, and trickle to the bottom, where they collect in B. It is advantageous, for the success of the experiment, to have the alcohol heated to about 90° Fahr. when it is poured in. In Germany, and other continental countries, where the duty on alcoholic liquors is not so high as in England, this method was once successfully followed, and for excellence and simplicity it can scarcely be surpassed. For operations on a large scale, a glass case, or one of wood, is constructed, the roof of which is of glass to admit the heat of the sun. In the interior of this case shelves are contrived, twelve inches apart, on which a series of shallow glazed earthenware or porcelain dishes are placed. The alcohol is poured into these vessels, and in each is a porcelain or stoneware tripod, bearing a watch-glass or small dish, containing the spongy metal. No more than an inch and a half, or two inches, should intervene between the platinum in the watch-glasses and the surface of the alcohol in the flat dishes. If there be no arrangement to supply an influx of air, in the place of that which becomes deoxidized, no more alcohol should be operated upon than the volume of air in the apparatus will be capable of converting into acetic acid. This quantity may be inferred from the fact, that one hundred and ten grains of alcohol require for their complete oxidation one thousand cubic inches of air, producing one hundred and twenty grains of anhydrous acetic acid, and about sixty-five grains of water. If a draught be instituted, by which the vitiated or nitrogenous portion of the deoxidized air is withdrawn, and

Fig. 2.

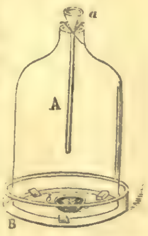
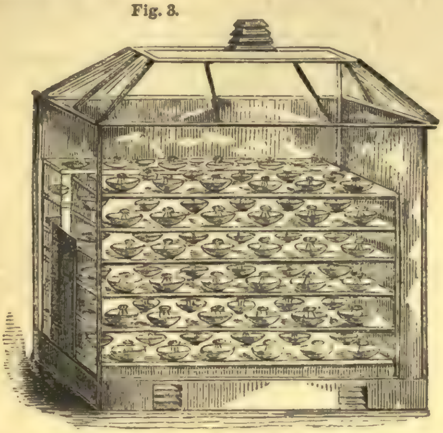


Fig. 3.



fresh quantities supplied by means of air-passages in the lower part of the chamber, the necessity of observing, with the accuracy mentioned previously, the amount of alcohol submitted to oxidation, is obviated. This arrangement is shown in Fig. 3. The temperature of the air in the case is raised by means of steam pipes or flues, from a fire adjacent to the apparatus, similar to those in vineries in this country, to about 90° Fahr.; oxidation of the alcohol commences, which is ascertained by the pungent odor of the acid. The elevated temperature converts a portion of the alcohol into vapor, which, on coming into contact with the moistened platinum, undergoes incipient combustion, giving rise to the acid. These vapors condense, and are collected, for the most part, in the dishes; the remaining quantity trickles down into a receiver at the bottom of the case. In this manner, the whole of the alcohol, in a comparatively short time, is converted into acetic acid; and as long as a supply of fresh air is kept up in the chamber, the spongy platinum retains its activity by inducing the oxidation of the liquid. With a case of twelve cubic feet capacity, and seven or eight ounces of platinum black, one pound of absolute alcohol may be acetified daily; and with a provision of twenty-four or thirty pounds of spongy platinum, and a proportionate sized case, three hundred pounds of alcohol may be oxidized in the same time, producing an acid of the purest kind. Hence this method claims pre-eminence over any other for the formation of acetic acid. The theory of this conversion of alcohol into acetic acid may be understood from the following representation. In the first stage of oxidation, the alcohol loses two atoms of hydrogen, which, by uniting with the oxygen of the air, give rise to water; there remains a peculiar volatile compound—aldehyde—which is the oxide of the supposed radical of acetic acid. The symbolical formula expresses this change:—

$$\underbrace{C_4\,H_5\,O,\,HO}_{\text{Alcohol.}} + O_2 = \underbrace{C_4\,H_3\,O,\,HO}_{\text{Aldehyde.}} + 2\text{ aq.}$$

The aldehyde takes up, in addition to the oxygen which it constitutionally contains, two atoms more, and thus passes into acetic acid, as is shown in the annexed equation:—

$$\underbrace{HO,\,C_4\,H_3\,O,}_{\text{Aldehyde.}} + 2\text{ aq.} + O_2 = \underbrace{HO,\,C_4\,H_3\,O_3}_{\text{Acetic acid.}} + 2\text{ aq.}$$

The following also represents the transformation:—

		Numerically.
1 atom of alcohol.......... =	$C_4\,H_5\,O,\,HO$	= 46
Minus 2 atoms of hydrogen....... =	H_2	= 2
Equal 1 atom of aldehyde.........	$C_4\,H_3\,O,\,HO$	= 44
Plus 2 atoms of oxygen......... =	O_2	= 16
Equal 1 atom of hydrated acetic acid	$C_4\,H_3\,O_3,\,HO$	= 60

Aldehyde is an exceedingly volatile body, a very slight heat being sufficient to dissipate it; and if this be not prevented by having a copious supply of fresh air in the case to oxidize it, a loss is suffered by the manufacturer. Every hundred parts by weight of alcohol require for oxidation sixty-nine parts of oxygen, producing one hundred and ten parts of acetic acid and sixty parts of water.

In every instance where alcohol or fermented alcoholic liquors are acetified, the principle of the conversion is the combustion of the alcohol of those liquors, by combining with oxygen. It has been stated that spongy platinum induces this change in regard to alcohol, but the same result is attained when other alcoholic liquids are exposed to the air at a slightly elevated temperature, in contact with a body in the state of fermentation, and in several other ways—which change has been called the *acetous fermentation.* In this manner, wine, brandy, beer, and, in fact, all liquids which undergo the vinous fermentation, are converted into solutions of acetic acid; and many liquids apparently pass at once into the acetous fermentation, especially those eviscerating a quantity of mucilage, and very little sugar. Alcohol in a pure state does not suffer the acetous fermentation, but if it contain vegetal matter, a metamorphosis occurs on its exposure to the air; hence the cause of the souring of wines, and the reason why weak ones do so sooner than strong, the former containing little spirit and much vegetal matter, while with the latter the case is contrariwise. If the vinous fermentation has completely ceased in those liquids, subsequently clarified, when exposed to the air at an elevated temperature they do not acetify; but if a ferment, in the shape of yeast, honey, or strong vinegar, should be added to such liquors; then, on the application of slight heat with access of atmospheric air, the intestine motion commences.

In all cases of acetous fermentation, where a quantity of liquid is exposed to the air, oxidation takes place at the surface only, and this occasions the conversion of their alcohol into acetic acid to extend over several weeks, or even months. Heat very much accelerates the change, inasmuch as a portion of the alcohol is converted into vapor, and this, carrying with it some of the ferment, in a state of eremacausis, communicates the same property to the vapor likewise, and acetic acid results; besides, imperceptible currents form in the liquids, by which fresh surfaces are always exposed till the work is completed. Spiritous liquors, on being exposed to the air in a state of fermentation, or with a ferment added to them, though ever so clear at the first, speedily become turbid, and slimy filaments appear through the solutions, which gradually adhere and rise as a spume to the surface. When this spume incrassates, it precipitates to the bottom of the vessel, and is called *mother of vinegar*. During the formation of this body an elevation of temperature is observed, a peculiar aromatic odor is evolved, and an acid reaction acquired; and towards the end of the operation, the temperature falls to about that of the surrounding air, the liquor clarifies, and, when it is siphoned off, constitutes the well-known liquid, Vinegar.

Before entering upon the manufacture of vinegar, it is deemed advisable to introduce the remarks of Dr. Ure relative to the acetous fermentation. They are clear and erudite, and may at some time or other prove serviceable to the consulter of these volumes.

Hitherto it has been generally imagined, that the formation of vinegar is accomplished by a peculiar fermentation, which has been called the *acetous*, in contradistinction to the *vinous*, the *panary*, the *putrefactive*, *et cetera*. But this doctrine is doubtful. The experiments serving as its basis, and which should reveal the nature of its peculiar ferment, as also the chemical reactions taking place in its progress, all seem to place this phenomenon somewhat out of the sphere of fermentation, properly so called. Every fermentation operates by resolving a body into compounds less complex than itself. But the so-called acetic fermentation serves to combine, on the contrary, two bodies, namely, alcohol and aldehyde, with the oxygen of the air; and this is the only case where fermentation produces such an action, which is a true combustion.

Yet it must be confessed, that the acetic seems to possess all the characters of the other fermentations; *videlicet*, the union of an organized body, or ferment, with a fermentable organic matter. The former is found in that spumous substance called *mother of vinegar*, and which is seen floating on the surface of vinegar in the act of its generation. With the acid fermentation it begins to appear, and it continues to be formed during its whole progress. It is at first a pellicle, composed of globules much more minute than those which constitute yeast; and they are often irregularly grouped. The pellicle becomes afterwards thicker in body and consistence, exhibits more distinct granular forms, and acquires a tendency to be distributed in strips or narrow bands. Of the reproduction of these globules the mode is quite unknown, but they seem somewhat akin to the slimy deposit of sulphurous mineral waters, called *baregine*.

If the study of the acetic ferment be mysterious, it is, nevertheless, clear that the conversion of alcohol into vinegar never takes place, in the common process, without the presence of an albuminous substance, and of the conditions favorable to all fermentations, besides the necessary access of air, not only at the commencement —as suffices for the vinous—but during all its course. Hence every weak spirituous liquor, which contains an albuminous matter or any ferment, may, with contact of air, and a temperature of from 60° to 90° Fahr., give birth to vinegar. If the mixture be too rich in alcohol, or if the nitrogenized matter be absent, or if the temperature be much above or below these two points, the phenomenon of acetification ceases. There are, therefore, several indications of the existence of a peculiar vinegar fermentation; though it should be observed, that the production of lactic acid—as from fermenting cabbage, starch, *et cetera*—has sometimes misled chemists into the belief of an acetic fermentation. The Editor will, on this account, point out briefly the distinction between the two processes.

The *acetic fermentation* requires the presence of ready-formed alcohol and the air; the *lactic*, on the contrary, proceeds with starchy or saccharine mixtures, without the intervention of alcohol or of atmospheric oxygen; and, when once begun, it will go on of itself. Acetification presents, moreover, a striking analogy with the phenomenon of nitrification, in the necessity of an elevated temperature, and the influence of porous bodies to divide the particles of the liquids and the air. Gaseous ammonia, for example, mixed with oxygen, when passed through a tube containing spongy platinum slightly heated, becomes nitric acid; when sulphurous acid gas and oxygen are passed through hot pumice stone, they become sulphuric acid; and when lime or potassa, diffused through porous matter, is placed in contact with ammoniacal emanations in the artificial nitre beds or nitrifiable soils, nitrate of lime or potassa is formed. In like manner, under the influence of spongy platinum, alcohol and air may, by a true oxidizement of the etherous part of the alcohol, produce aldehyde, which passes afterwards into acetic acid and water; as is, hereinafter, represented:—

Thus alcohol, $C_4H_5O, HO = C_4H_4O, \quad + \quad H_2O$
Plus two of oxygen, ... $\quad O \quad\quad O$

Equal aldehyde, ... $\quad C_4H_4O_2, \quad + \quad H_2O_2 = 2\,HO,$
Plus two of oxygen, ... $\quad O_2$

Equal acetic acid, ... $\quad C_4H_4O_4 + 2\,HO = C_4H_3O_3 + 3\,HO.$

Donovan gives some interesting details upon the phenomena of the acetous fermentation, and as they differ in the main point from those of other chemists, extracts from them are appended, with a few observations by the Editor, showing how far they may be relied upon.

With regard to the theory of the acetous fermentation, and the formation of vinegar, little is certainly known. It may be admitted as a fact, that it is almost exclusively the alcohol of the fermented liquor which is changed into acetic acid; and the query is,—What is the nature of the transformations? Lavoisier, finding that oxygen is absorbed during acetification, concluded that its presence and absorption are indispensably necessary; that the oxygen enters into the composition of acetic acid; that acetic acid is alcohol *plus* oxygen; and that the change effected by the acetous fermentation is the oxidation of the alcohol. But the facts stated by Saussure tend to prove, that the oxygen absorbed during the acetous fermentation does not enter into combination with the alcohol; but acts the very different part of abstracting some of its carbon, combining with it, and thus forming carbonic acid, which then remains a separate compound, either exhaling or remaining mechanically mixed with the resulting liquor. Vauquelin conceived that the ferment takes both hydrogen and carbon from the alcohol, leaving therefore an increased ratio of oxygen, and thus converting it into acetic acid, while ammonia and an oily substance are formed; but the production of these two compounds seems not to have been ascertained.

Theories have also been brought forward to account for the formation of vinegar during the acetous fermentation, founded on the belief that the agency of the oxygen absorbed is to remove carbon and hydrogen from the alcohol, by the formation of carbonic acid and water; for it is known that acetic acid contains less carbon and hydrogen than alcohol. A theory of this kind, however, has to contend with the fact, that although oxygen is sometimes absorbed during the acetous fermentation, and carbonic acid formed, this absorption seems to be effected by some other carbonaceous matter present in the liquor, and not by the carbon of the alcohol: for, were this the case, the absorption of oxygen would be indispensable; *yet vinegar may be formed perfectly and with ease, even though the access of air be totally prevented.* This fact is proved by many instances. BECCHER included wine in a glass bottle, which it filled, and hermetically sealing the mouth, he exposed it to a digesting heat; after some time the wine was converted *into very strong vinegar.*

FOURCROY and VAUQUELIN obtained vinegar from a solution of sugar contained in close vessels. HOMBERG included good wine in a bottle, and, having closed it accurately, he fastened it to the sail of a wind-mill: in three days *it was very good vinegar.* It is a fact well known to every one, that a bottle filled with weak beer, and closely corked, will in some time be converted into vinegar. It may be said that air was absorbed through the cork; but this could scarcely happen, for after a cubic inch or two of oxygen would thus be absorbed, the neck of the bottle would be filled with nitrogen, and there being now no longer the aid of a partial vacuum, it is hard to conceive how air could enter. But the experiment of BECCHER seems to me irrefragable; and I think we are bound to admit, that the absorption of oxygen during the formation of vinegar is incidental, not necessary.—*Donovan.*

BECCHER states that the bottled wine was converted into very strong vinegar merely by exposing it to a digesting heat. The *strength* of the vinegar is not stated. It is well known that wine and other liquors include several cubic inches of atmospheric air, and it was no doubt the oxygen of this, aided by the heat, that produced the acetic acid. The wine must have contained upwards of twelve per cent. of alcohol; now vinegar containing two or three per cent. of acetic acid is considered good, and the Editor has no hesitation in saying, that there was sufficient oxygen in the wine used by BECCHER to produce vinegar of the above strength; therefore, this experiment does not at all do away with the opinion, that air or oxygen is necessary for the conversion of alcohol into acetic acid. The same reasoning will apply to HOMBERG'S experiment. The agitation his wine received on the sail of the windmill, would induce the combination of the alcohol with the oxygen contained in the liquid and that absorbed *through the cork.* Did not the wine in BECCHER and HOMBERG'S experiments contain a large quantity of spirit after being submitted to the agitation and digesting? If so, the deductions drawn by the Editor infallibly prove, that oxygen is necessary for the conversion of alcohol into acetic acid.

Vinegar is, according to the nature of the sources whence it is obtained, classed into several varieties. Of these the chief kinds are wine vinegar, sugar vinegar, malt vinegar, wood vinegar, and fruit vinegar, dependent, however, upon the presence of acetic acid as the first active principle, although they each possess a flavor and aroma peculiar to themselves; and on this account preference is given to some kinds of vinegars. All are produced by the acetous fermentation, except wood vinegar.

WINE VINEGAR.—*Weinessig*, German; *Vinaigre*, French.—This species of vinegar is chiefly fabricated in wine-growing localities, or where grapes are abundant, the principal factories being at Orleans in France. The building where the work is carried on is called a *vinaigrerie*, and has always a southern aspect. The casks, called *mothers*, which are employed, hold from fifty to one hundred gallons, and rest upon strong wooden frames, supported by pillars of wood or stone of eighteen inches in height. Several such casks are placed in rows, and when acetification is carried on in the open air, eight, ten, fifteen, or twenty such ranks constitute what is termed a *vinegar-field.* Two holes are bored in the upper surface of the front end of each cask; the larger serves to charge the cask with wine, as also to draw off the vinegar when formed, and the smaller allows an influx or efflux of air as the cask is emptied or charged. The chief aim of the person who wishes to carry on a vinegar factory, is to have a good fermenting-room, where the wines are exposed to an even temperature, having a copious supply of atmospheric air and moderate ventilation—the air-holes for this purpose being constructed so as to admit of being closed in windy weather, or when the temperature of the room is depressed. The walls of the apartments are of brick, or such non-conducting material, and lined with lath and plaster.

Low-roofed apartments are the most suitable; when there is a high ceiling it is necessary to elevate the mothers, in order that they may occupy the higher strata of warm air—this trouble is dispensed with when the roofs are low. Experience has pointed out, that in high-roofed apartments, where the tuns are placed at different levels, the uppermost work off quicker and better than the others. In the event of new mothers or vessels being used, it is needful to fill them one-third full with the strongest vinegar at a boiling temperature. This forms the stock, or true *mother;* the charges of wine added each time are two and a half gallons to every cask, and an interval of eight days is allowed for the acetification of each charge, before adding another of fresh wine. This treatment is continued—of charging, and allowing eight days to work it off—till the casks are more than half full. One-third of the contents of each mother is then siphoned off—in some factories only ten gallons—and run into the store tuns, and the process repeated anew of charging every eight days till the mothers are refilled, as before. Some manufacturers do not suffer the vinegar to remain in the mothers till they are two-thirds full, but siphon off, at the end of every sixth or eighth charge, twelve or fifteen gallons of vinegar. The mothers should never be charged with more than the above quantity, in order to carry on a steady and efficient mode of acetification. Occasionally it happens that eight days are not sufficient to finish every charge; this is more unaccountable from the fact, that the backward casks receive the same amount of care, and have the same temperature, as those which work well. It often occurs that the casks in the warmest part of the room are those which are backward, or *lazy*, as they are termed. In this event, nothing remains but to empty such mothers of their contents and fill them with hot strong vinegar, when, on adding fresh charges, the acetous fermentation recommences, and goes on as briskly as in the rest. Sometimes fresh quantities of a stronger wine, and an increase of temperature, are supplied, to quicken the fermentation in such casks—which mode is often successful: the *laziness* of the mothers is attributed to very vague and unsatisfactory causes, some regarding it as the effect of the electrical state of the casks and liquid.

It has been recommended to isolate the mothers as much as possible, and to use little or no iron in the construction of the casks. To ascertain if the liquor has fermented, the following experiment is resorted to. A white rod, bent at one end, is plunged into the mothers, and drawn out in a horizontal direction; if the rod be covered with a thick white froth—flowers of vinegar—the operation is said to be terminated; if the froth be reddish-brown more wine is added, and the temperature increased till the whole is acetified. In summer the natural heat is sufficient, but in winter the mothers are heated, by means of a stove, to about 80° Fahr. The prevailing temperature should range between 75° and 80° Fahr. When proper attention has been paid to the manufacture, the mothers usually work off double their contents of vinegar annually. The precipitation of the insoluble matters of ferment, the accumulation of *mother of vinegar*, and the deposit of tartar from the wine, fill the casks to such an extent that it is indispensable to empty the whole of them, and free them from these deposits every six or eight years—and often the entire factory needs renovation, as was the case with a malt vinegar one in Liverpool, which the Editor recently inspected; but good casks will last for a period of twenty-five years. The wine, if it be ropy, is introduced into a large tun filled with beechwood shavings, through a funnel opening in the cover, and allowed to repose for some time, whence it is afterwards drawn off by a tap in the lower part of the tun, and supplied to the mothers as required. Frequently, when weak wines are employed, from the proportionably large amount of vegetal matter they contain, it happens that the resulting vinegar is ropy and turbid; in these instances, it is necessary to pass it through the clarifying or *fining* tun, and the advantage of having an average vinegar is gained.

The old method, introduced by **Boerhaave**, is still practised in Holland, in France, and on the Rhine. Two large tuns or vats, about nine feet high and four feet in diameter, are supported on stands, about twelve inches from the floor. Within one foot from the bottom of each vat is a perforated bottom or wooden grate, resembling that of a riddle; on this a quantity of fresh cuttings from the vine, willow twigs, *et cetera*, is placed, and pressed closely together, the remainder of the vats being filled with *rapes*—the footstalks of the grapes—and other light branches. Both vats are left open for the admission of the extrinsic air. They are then charged with wine; one is completely filled, the other only half. The two are left at rest for twenty-four hours at 75° Fahr., after which the half-filled vat is replenished from that already full, till the latter contains only half its contents of liquor; twenty-four hours elapse before the liquid is retransferred from the filled to the half-filled vat.

The process of transferring the liquid into the vats alternately, is repeated every twenty-four hours until the vinegar is made. Towards the third or fourth day an internal effervescence is observed in the half-filled vat, which is accompanied by a sensible elevation of temperature, increasing gradually each successive day. On the other hand, the temperature and fermenting action of the filled vat are but sluggishly progressing, so that the intestine motion takes place only on alternate days in each vat. The completion of the process is known by the decreased temperature and abated action even in the half-filled vat. The vinegar is then drawn off into casks, and left in a cool situation till it clarifies. During summer, the time occupied is fifteen days; but in winter the acetification extends over a longer period. The temperature of the half-empty vat should never exceed 80° Fahr.; if it rises to 84°, the liquor is to be transferred every twelve hours, and an oaken cover placed on the half-filled vat in order to check the fermentation, otherwise the aldehyde, or half-made vinegar, will be dissipated, and only a vapid fluid remains, sour, but effete. If the whole be kept at 83°, and the menstruum transferred every twelve hours, the acetification will be effected in eight or ten days. According to **Dumas**, the best French vinegar is made of good wine, which is put into a cask already containing vinegar, and to which atmospheric air has constant access. As acetification proceeds, more wine is added at intervals, and when the whole has become vinegar, it is drawn off to the amount of the wine used, and the process is repeated. Its strength, flavor, and color, depend upon the characters of the wine employed. The temperature of the factory is maintained at 86°.

Mulder, the celebrated chemist of Utrecht, has given a very interesting account of the vinegar mother or ferment — *Mycoderma aceti* — which the Editor appends:—It is self-evident, says **Mulder**, that the origin of organized beings from non-organized substances, must depend upon a transmutation. Researches for the purpose of explaining this point must evidently proceed from the most simple case: such a case is the formation of the so-called vinegar mother, a plant originating in the vinegar, and, in fact, at the expense of its constituents. This cryptogamous vegetal may justly be regarded as one of the most simple vegetal formations, and belongs rather to the Fungi than to the Algæ. Fruit-bearing organs, with globular sporidia, could never be detected in this species which grows in the vinegar—*Mycoderma vini* and *Mycoderma cerevisiæ*, which probably constitute one species. It does not originate in wood vinegar, but always in wine and beer vinegars, causing whole vats of it to pass into water. The vinegar mother is also often found in vinegar in which organic substances have been preserved; however, these substances contribute nothing to the development of the mould plant, they only further the origin of a germ, a cell, which separates from the mass, and now, as a germ, forms a plant from the elements of the acetic acid.

From wine vinegar, in which totally different substances have been preserved, the very same species of *Mycoderma* was developed, the same organized structure, the same mould plant, identical in form and in chemical composition.

The principal constituents of the wine vinegars are, acetic acid, $C_4\,H_3\,O_3$, and water, H O. They contain also some salts, a small quantity of sugar, gum, and extractive substance, and, above all, some protein, derived from the albumen of the grapes, dissolved in the acetic acid. In vinegar in which vegetal substances —for instance, gherkins, cherries, *et cetera*—have been preserved, the quantity of the protein may be increased from these vegetals; but that this is not requisite, is evident from the formation of the vinegar mother in pure wine or beer vinegar. The aliments of this vegetal mould are, therefore, $C_4\,H_3\,O_3$, H O, and $C_{40}\,H_{31}\,N_5\,O_{12}$.

Now, these constituents are found to be grouped in a very simple manner in the plant, while both protein and acetic acid disappear from the liquid; moreover, the plant contains nothing else, and we are, therefore, able to follow chemically the transformation of acetic acid and protein into a plant.

It is not less remarkable, that the plant has always the same chemical composition; and the organization, consequently, requires a definite proportion of acetic acid and protein, the latter of which remains unaltered, while the former yields a cellular substance under absorption of water. The new product of the acetic acid combines in atomic proportions, just as well as the formation of gypsum from carbonate of lime and sulphuric acid.

The vegetal mould examined by MULDER was taken from vinegar in which some substances had been kept. Although always wine vinegar, the samples were of various origin, and had preserved the following:—

No. I., Currants.
No. II., Cucumbers.
No. III., Gherkins.

In the last it formed very rapidly. The first traces of it were observed five days after placing the substances in the vinegar; on removing the first crust, the second formed in the course of a week, and so on for the five subsequent weeks, always a new one, although the vessel was well closed. The strength of the acetic acid decreased more and more, until, at last, only water remained: all these crusts had the same properties. The species of *Mycoderma* examined, always formed a coriaceous membrane, more or less elastic, saturated with vinegar, and of a white color, except that from the vinegar of the currants, which was reddish. By kneading and pressing, the membrane becomes void of taste and smell. Neither water nor alcohol dissolves anything from it by boiling. On incineration, it does not leave the slightest trace of ash; submitted to destructive distillation it affords much carbon, and an acid liquid distils over, from which potassa liberates ammonia. It is not altered by cold strong sulphuric acid; but in the heat it becomes first red, then, under decomposition of the sulphuric acid, brown, and lastly, black. Concentrated nitric acid colors it yellow, and on the application of heat it dissolves very slowly in it; hydrochloric acid has no sensible action upon it; strong acetic acid takes up, when boiled with it, some protein, the presence of which can be demonstrated by ferrocyanide of potassium.

When well purified with water and alcohol, it ceases to lose any more weight at from 248° to 275° Fahr. The analysis of the three kinds gave:—

	I.	II.	III.	Theory.
Carbon,	46·75	46·89	46·89	46·60
Hydrogen,	6·51	6·52	6·50	6·40
Nitrogen,	—	—	3·87	3·96
Oxygen,	—	—	42·74	43·04
			100·00	100·00

By long digestion with potassa, and continued boiling with acetic acid, the whole of the protein may be extracted, leaving pure cellulose, which is not combined with any other body. This cellulose, which was examined by PAYEN and others, has the formula, $C_{24}\,H_{21}\,O_{21}$, or that of the solid modification of inulin, which ROSÉ obtained as a white precipitate during the cooling of a strong decoction of elecampane root. PAYEN procured it from the grated root of the dahlia.

By following the mode of formation of the plant from the vinegar, the first thing observed is, that the protein which was present in the vinegar as albumen from the grape, passes from the dissolved state into a solid, synchronously, assuming an organic form. On employing wood vinegar, the protein must be furnished by the vegetal substances which had been preserved in it; but, as above stated, pure wine vinegar also produces vinegar mother; the cellulose, therefore, can have originated solely from the acetic acid.

$$\underbrace{C_4\,H_3\,O_3}_{\text{Acetic acid.}} \times 6 + 3\,H\,O = \underbrace{C_{24}\,H_{21}\,O_{21}}_{\text{Cellulose.}}.$$

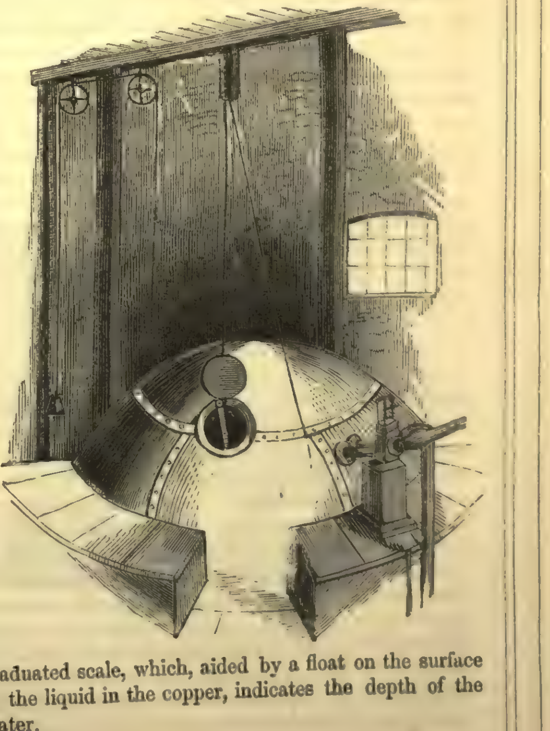
MALT VINEGAR.—*Malz-Getreide-oder-Bieressig*, German.—In this country, the chief part of the vinegar is made from *malt wash*, or *gyle*, prepared by operating upon the materials in the annexed proportions:—Six bushels of good barley malt, properly ground, are mashed with forty gallons of water at 160° Fahr., permitted to repose till the solid matter settles down, the solution drawn off, and the residue affused with a fresh quantity of water, say forty gallons, at 180°, well agitated for a short time, allowed to settle, then siphoned off as before; and to take up all the soluble matters, the third washings may be performed with boiling water. On the whole, not more than one hundred gallons of wash is to be used in extracting the soluble matters. When the solution has cooled to about 75°, it is well agitated with four gallons of yeast of beer; and after thirty-six or forty hours, raked off into casks, and placed in the vinegar stoves or apartments, the temperature of which should range from 70° to 77° Fahr. The casks should be placed on their sides, the bungholes opened, and a circulation of air kept up in each cask by means of an orifice bored at each end of the cask, near its upper edge. Since the temperature of the liquid is somewhat less than the surrounding atmosphere, in consequence of the evaporation at the surface, an efflux of cold air takes place at the holes while the warm air enters at the bung, and thus a constant current is kept up. Frequently this manufacture is effected by *fielding:* the casks rest on strong frames, one foot and a half high, being supported by firm pillars of brickwork or wood. Six or eight rows of these are arranged parallel to each other, with a narrow walk between each pair of rows; a sluice is placed along the casks into which the vinegar is siphoned, whence it flows into the store tuns in the magazine; and a flexible tube, or hose, supplies the *wash* from the great tun in the brewhouse. The bungholes are left open in dry, and are loosely covered with a tile in rainy weather. One-third of each *mother* is left empty for the circulation of air, so as to oxidize the alcohol as it generates in the wort. Three months are required to complete the process, and render the vinegar marketable.

What constitutes malt is generally known, but it may be stated here, that the process of malting changes the character of the grain, by converting some of the starch contained in the barley into sugar, and facilitating the similar conversion of a further portion. This conversion into sugar, called the *saccharine fermentation*, is one of the important steps in the preparation of beer, whisky, and malt vinegar: in all of these it is requisite that the starch of the grain be converted into a kind of sugar, for it is from this that the vinous fermentation produces alcohol, the parent of vinegar. Hence the early processes in an ale brewery, a malt distillery, and a malt vinegar works, are similar.

In the factory about to be described, the malt is hauled up out of the waggons into the upper floors of the brewhouse. Here openings, placed in different directions, permit of the malt being poured down into large bins, whence it is removed when a brewing is going to commence. Vinegar-makers and distillers, as well as beer-brewers, give the name of *brewing* to the extraction of a saccharine liquor from malt. The quantity required for one brewing being measured out, and taken from the bins in sacks, it is poured through *hoppers*, or funnels, at the top of the grinding apparatus, whereby the malt is reduced to meal. The apparatus consists of both the kinds used for such purposes, *videlicet*, millstones and crushing-rollers, either or both of which can be employed as may be deemed advisable. In the one case, a flat circular stone rotates and crushes beneath it the malt, which flows between it and a lower fixed stone: in the other, the malt, after flowing through a shoot or trunk from the hopper, falls on a wire grating, where it becomes depurated. It then passes between two cast-iron rollers, rotating nearly in contact, by which means it is crushed into fragments. An ingenious contrivance, says DODD, invented by Captain HUDDART, is adopted for yielding to any hard substance which may enter between the rollers and the malt, without injury to the apparatus; it acts on the principle of stopping the circular motion of the rollers altogether, until the cause of hindrance is removed.

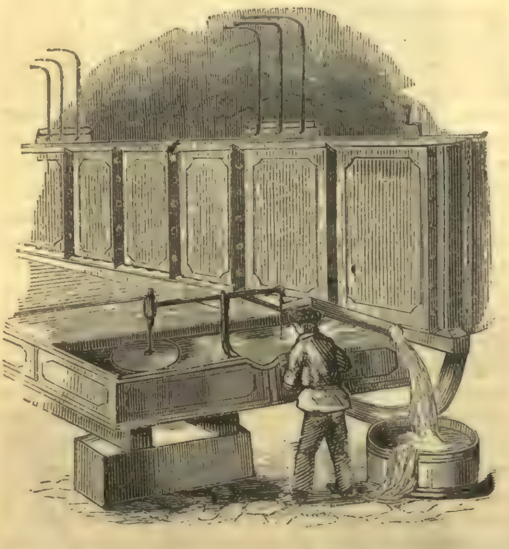
When the malt is crushed or ground, it falls through a hose or trunk into the mash-tuns in the floor beneath. These mash-tuns are similar to those used at large breweries and distilleries, but smaller in size. They are circular vessels, with a central *stirrer*, or instrument for keeping in constant agitation the ingredients contained in the tuns—the stirrer being worked by a steam-engine. It is in these vessels that the *saccharine fermentation* proceeds, or the extraction, by the action of hot water, of a sweet or mawkish substance from the malt. This is the sweet principle which subsequently yields to the brewer, his beer; to the distiller, his spirit; and to the vinegar-maker, his acetic acid: and it may well be supposed, that every precaution is taken, and every investigation made, as to the extraction of the greatest quantity, and the most fitting quality, of this important agent. The quantity of water required for a given quantity of malt, and the temperature at which the water is used, vary in each particular branch of manufacture, according to the strength of the *wort* required. The arrangements for settling these are very exact and ingenious. Hot water is let down upon the malt in the mash-tun, when at the proper temperature; and in order to adjust this, the foreman of the brewhouse ascertains, by the aid of a thermometer, the temperature of the water through a temporary opening in the upper part of the boiler. This is shown in Fig. 4, where is also represented a balance-weight and graduated scale, which, aided by a float on the surface of the liquid in the copper, indicates the depth of the water.

Fig. 4.



When the water has acted on the malt for a certain period, and been constantly stirred with it, the liquor receives the name of *wort*, and is allowed to flow through pipes out of the mash-tuns into a large cast-iron tank, or *underback*, measuring twenty-four feet or upwards in length, by eight in width. This is merely a general receptacle for the wort, into which the latter is collected when the mashing is completed. Then ensues the process of *cooling*, one which exhibits many remarkable differences, as effected in different establishments. Large, open, shallow, airy rooms, called *coolers*, or *cooling-floors*, whereon the wort was poured in a thin layer, to be cooled by the access of air on all sides, was formerly the mode adopted at the vinegar works now under description; a surface of nearly twenty-three hundred square feet having been appropriated to this purpose. This mode has, however, been superseded by another, in which one hundred square feet of surface is made to yield the effects formerly wrought by more than twenty times that extent. There is a vessel now employed for this purpose, called a *refrigerator*, which acts on the following principle:—The hot wort is allowed to flow out of the underback into an oblong vessel, and out of this into another receptacle in the same part of the building. A continuous pipe, between three and four hundred feet in length, passes backwards and forwards through the oblong vessel, and through this pipe cold water flows incessantly, from an Artesian well two hundred feet in depth. Constant currents of wort run in one direction through the apparatus, while a current of water in an opposite direction flows through the pipe which cools the wort.

Fig. 5.



The temperature of the wort may be cooled even to that of the water were it required, either by increasing its influx and retarding its efflux, or by permitting a larger quantity of water to flow through the pipe. The heat of the wort is abstracted by the colder medium with which it is in contact, so that the liquid becomes colder as it passes to the exit pipe till the proper temperature is attained—the flow of wort and water being regulated by suitably adjusted valves, which admit of the proper quantity of each liquid. Fig. 5 represents the refrigerator at the end where the wort enters, and where the water leaves the pipe, after having performed its office; collateral with the refrigerator is the underback. Not only does this method require much less room than that of the cooling-floor, but the refrigeration is greatly accelerated, and the manufacturer is rendered independent of the fluctuations of the weather; for his refrigerating agent being brought from a source two hundred feet below the level of the ground, has, summer and winter, nearly the same temperature.

The reader must bear in mind, that the wort produced is precisely the same as that made by the beer-brewer and the distiller, differing solely in saccharine strength. It suffers likewise the same process of fermentation, subject, of course, to any limitations that may be required by its nature. From the refrigerator, the cooled wort flows into the *jack-back*, a large circular receptacle sunk in the ground, whence it is pumped up into fermenting tuns. A valuable system of combination or centralization is observable in the arrangement of the conducting pipes.

Large vessels are clustered, serving as a kind of common centre, from each of which openings lead to several other vessels, each orifice being regulated by a particular valve; for example, the liquid which, in various processes, is contained in the jack-back, has sometimes to be transferred to the fermenting tuns, at one time or other to a large back or cistern at the top of the building, and oftentimes to the copper; still there are not *three* openings from the jack-back for these several purposes, but *one*, which leads to a three-barreled pump, the barrels of which are respectively marked *tuns, back, copper;* so that, by turning one of three handles, the liquid can be conveyed to either one of these. Again, the back just alluded to is placed in connection with several other large tuns or backs, in different parts of the premises, to any one of which its contents can be transferred by simply turning a handle. An hexagonal table is in one of the buildings, under the surface of which are six valves, all opened and shut by one key. On each tap the name of some particular vessel or building is inscribed, with which it is in adunation by an extensive series of subjacent pipes; and the overseer of this small piece of apparatus can control, in almost any direction, the flow of the liquid under manufacture. Such a system of classification is excellent.

The *gyle* is transferred from the fermenting tuns to other large casks, where it deposits, in course, a kind of acetous yeast—mother of vinegar; and being thence permitted to flow into the jack-back, it is drawn up one of the branches of the three-barreled pump into the large vat at the top; from this, as a centre, the gyle is allowed to flow into casks, where, after a longer or shorter period, it assumes the form of vinegar.

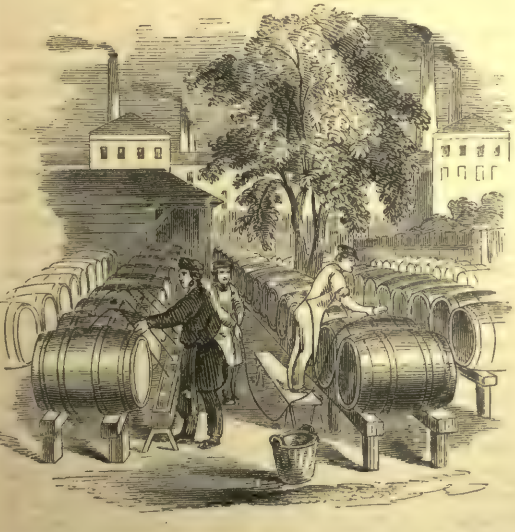
Transformation of the fermented wort into vinegar is effected at the factory in two ways, which are entirely opposite in their manner of operation. In the one case, the casks containing the gyle are placed in close rooms, heated to a high temperature; in the other, they are ranged in rows in an open field, where they remain many months. Different as these methods seem to be, yet the effect produced is precisely the same; *videlicet*, the conversion of the gyle into vinegar, by the process of acetification. As regards the convenience and interests of the manufacturer, both methods seem to have their several advantages; for at the vinegar works under consideration, both are followed, although one occupies a very much longer period of time than the other.

When *fielding* is resorted to, it must be made during the spring months, and then left to finish during several months in the warmth of the season. Technically, the other process is called *stoving*, and in this case the casks containing the gyle are arranged conveniently in three stove-rooms, which are closed and locked, and then exposed to a certain temperature till the acetification is concluded. A cursory visit to one of these apartments readily convinces us of the progress of the fabrication, by the pungent acetous odor of its atmosphere.

The fielding method requires a much larger extent of space, and other utensils, than the stoving, from the peculiarities always attendant upon it.

The casks, as already described, are placed in several lengthy parallel tiers, with their bung-side upwards, and left open. Beneath some of the paths which separate the rows of casks, are pipes, communicating with the back at the top of the brewhouse; and in the centre of each of these paths is a valve, or opening into the concealed pipe. When the casks are about to be filled, a flexible hose is screwed on to this valvular opening, the other end of the hose being inserted into the bung-hole of the cask, and the liquor in the gyle-back at the brewhouse, by its hydrostatic pressure, flows through the underlying pipe and hose into the cask. The hose is so long as to admit of reaching to all the casks in the same row, from the valve, and is guided by a workman, as is seen in Fig. 6. After due time the vinegar is made, and is drawn off by the following ingenious operation. A long trough or sluice is laid by the side of one of the rows of casks, into which the vinegar is transferred by means of a siphon, whose shorter limb is inserted in the bung-hole of the cask. The trough inclines a little from one end to the other, and its lower end rests on a kind of traveling tank or cistern, wherein the vinegar from several casks is collected. A hose descends from the tank to the open valve of an underground pipe, that terminates in one of the buildings or stores; and by the agency of a steam-boiler and machinery in the adjacent buildings, the pipe is exhausted of its air, and this causes the vinegar to flow through the hose into the valve of the pipe, and thence into the factory buildings. By this arrangement the whole of the vinegar is drawn off, and, as if it were, invisibly. This arrangement is partly seen in the engraving. From the storehouse where the vinegar is received, it is pumped into the *refining* or *rape* vessels, and filtered, to separate mucilaginous matter. These vessels are often filled with wood shavings, straw, or spent tanners' wood, but none of them acts as a substitute for the stalks and skins of the grapes—rapes—in producing by filtration a bright vinegar.

Fig. 6.



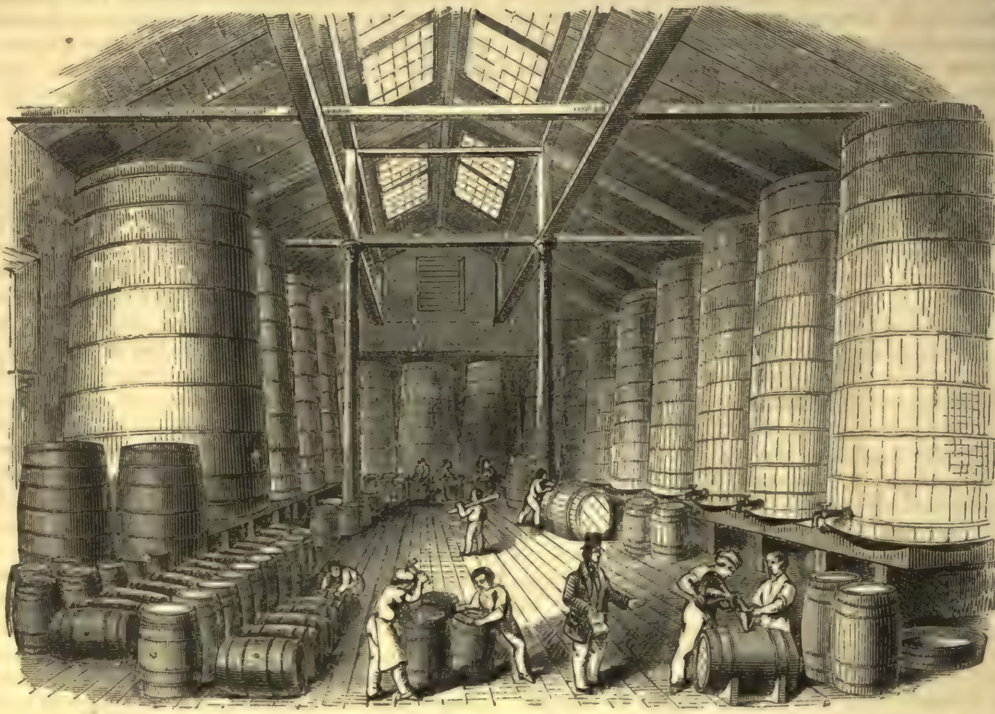
It is a matter of difficulty to collect a proper stock of rapes, to supply a filtering medium for a large vinegar work, when several huge refiners are in operation; and, when once collected, no part of the materials relating to the factory are treasured with so much care.

Dodd describes each rape or filtering vessel as being fitted with a false bottom, on which the grape stalks are placed. Beneath this false bottom, and above the true one, a tap is inserted, which allows the vinegar to flow into a back or cistern. From this cistern a pump elevates the liquid to the top of the vessel, and hence ensues a very curious circuit: the vessel is filled with vinegar, which filters through the raisin-refuse into the space beneath, from there into the tank, thence through the pump to the top of the vessel, to recommence its circuit. Over and over does this circuit proceed, the pump being kept constantly at work, and the vinegar incessantly in motion. If such a comparison might be permitted, we would liken the pump to a heart, which propels the liquid to the enormous lung—the rape—where it is depurated, and then again returned to the heart. The filtering substance gradually, but very slowly, wastes away, but is renewed from time to time.

Vinegar, by this process, becomes transparent, or *bright*, as it is technically termed, and is then pumped from the rapes into store-vats, where it is kept till required to be put into casks for sale; and the rapes are immediately filled up with an equivalent portion of fresh vinegar, so as never to leave the raisin-refuse idle. The vinegar casks hold one hundred and sixteen, fifty, and twenty-five gallons, respectively. Each cask is examined and gaged before being brought into the *sending-out warehouse*, to see that it is sound and of proper dimensions. The warehouse is a large room, lined on all sides by store-vats, from which the casks are filled; and on the days when these casks are to be despatched, a very busy scene is presented with coopers, porters, *et cetera*, ranging the casks, marking them, and consigning them to the waggons.—See Fig. 7.

Vinegar for household purposes is made in the following manner:—The malt being prepared in the usual way, a quantity of *argol*—winestone—is added, and afterwards introduced into the casks. The casks have a perforated bottom, about a foot above the true one, and are placed on their end. A quantity of refuse of raisins, from wine factories, is placed on the false bottom, and the wash at the temperature of 70°—a proper addition of yeast being previously made—is poured upon the rapes in the casks. After twenty-four hours the wash is racked off into another cask of the same description, and allowed to remain in this for a day or two, when it is drawn off into a third and fourth cask. The liquid, after spending twenty-four hours in the last cask, is raked off and supplied to the mothers; then allowed to ferment quietly, as in the preceding instances, at a temperature of 70° Fahr. Argol communicates to it the appearance of wine vinegar. It is clarified by leaving it in the casks, for some time, with a little isinglass.

Fig. 7



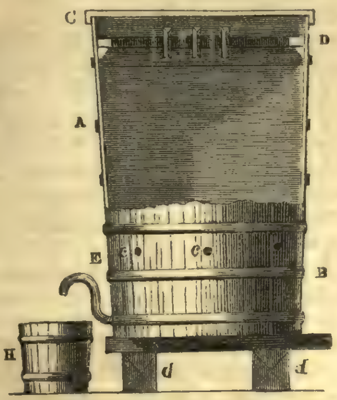
Sugar and Cider Vinegar.—In many factories, instead of a sweet wort of malt, a solution of sugar is often employed to produce vinegar. Several receipts are given for this department of the manufacture, the principal being the annexed:—Dissolve ten pounds of sugar and six pounds of winestone in forty gallons of boiling water; put the solution into the fermenting tun, and when cooled down to 80°, add four quarts of beer yeast, and agitate the whole thoroughly. Grant the liquid repose for six or eight days, at a temperature of 75°, till the vinous fermentation is ended; after which rake it off, and submit the liquor to the acetous fermentation, either by one or other of the modes already mentioned, or by the *graduator* process, which will be presently described. Another prescription is—

100 parts of water, 13 parts of brandy, 4 parts of honey, 1 part of tartar,	or	120 parts of water, 12 parts of brandy, 3 parts of brown sugar, and 1 part of tartar,

—surrendered to the usual processes till the acetous fermentation is fulfilled.

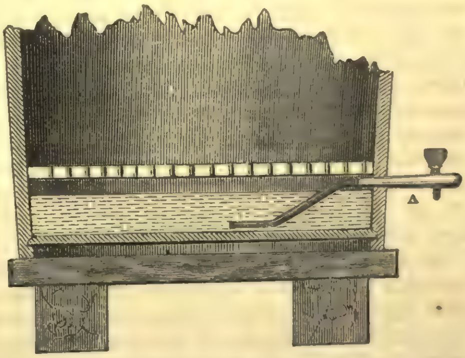
Quick Vinegar Process.—*Schnellessigbereitung*, German.—From the length of time necessarily occupied in making vinegar, as hitherto described, the name of *slow vinegar process* has been given to the manufacture since the application of a quicker method for accomplishing the same end. Of the older methods, the only approximation to the process now considered, was that of BOERHAAVE, described under Wine Vinegar, at page 7. Mr. HAM of Bristol patented, some thirty years ago, a process very closely resembling the *graduator*, but much inferior, inasmuch as the surface exposed to active oxidation was far less in the former than in the latter. Good vinegar is at present made from alcoholic liquors, in the course of thirty-six to forty-eight hours. The slow and quick processes are conducted upon the same principle, namely, the oxidation of the alcohol; but the manner in which it is oxidized is different—the surface exposed in the quick method being many thousand times more extensive than in any former one. Before entering minutely into the arrangement of the vessels employed, it will be as well to state curtly, that an extreme division of the liquor is effected, as when it comes into play it can only percolate very slowly, and thus diffusing itself over shavings, forms a very thin liquid layer, the surface of which is exceedingly large, and is therefore better adapted for the chemical appropriation of the oxygen in the current of air which is transmitted over it. A gallon of liquor, when subjected to the quick method of acetification, if allowed to percolate slowly, offers a surface of about one hundred square yards to the action of the air during its descent.

Fig. 8.



The graduator, which Fig. 8 represents, is a large tub or tun, A, of oak, eight feet high, three and a half feet diameter at bottom, and four feet at the top, and rests upon a stage, *d d*, of wood or brickwork, one foot and a half high. A stout hoop of beechwood is fastened in the interior of the tub at B, eighteen inches from the bottom, and a perforated shelf placed thereon; and two inches above this, eight or ten holes, *c c*, one to one and a half inch diameter, are bored, equidistant round the cask, and inclining downwards from the outside. Another strong beechwood hoop, D, is fixed a foot from the top of the tub, on which is placed a second perforated cover, fitting the interior of the vessel tightly —the holes being one inch apart, and one-fourth of an inch in diameter. These apertures are loosely filled with cotton wick or packthread, a knot being made at the top end to keep them from falling through the cover; they pass down to the shavings, and serve the purpose of conducting the liquor equally through the body of the tub, as likewise to arrest it from passing too rapidly through the tun. The space between the bottom and top shelves is filled with shavings of beechwood, and a thermometer is introduced a little below the top cover, the bulb of which reaches the middle of the apparatus, to indicate the rise or fall of temperature, as the subsequent oxidation of the alcohol is greater or less. Six larger holes are bored in the upper cover, one and a half inch in diameter, into which wooden or glass tubes, opening below it, and about nine inches long, are adjusted; these serve as chimneys to carry off the deoxidized air from the vessel. A loose oaken cover, C, with a funnel opening in the centre, through which the liquids for charging the graduator are supplied, protects the whole from dust, *et cetera*. At one and a half or two inches from the bottom of the graduator, a pipe or glass tube, E, is inserted; it bends upwards nearly as high as the lower perforated shelf, and then curves extrinsically, so as to discharge the liquid into an appropriate vessel, H, placed beneath it, when it rises so high as the shelf in the interior of the vessel. A wooden pipe, twelve or fifteen inches long, is fixed in the lower part of the vessel—see Fig. 9 —having a plug or wooden screw fitting the bore of the pipe, that acts as a tap, by which the dregs and other albuminous matters that accumulate are run off. Everything being thus arranged, hot strong vinegar is poured through the funnel opening in the outer cover, and passed through the graduator for one or two days, to induce an eremacausis or slow combustion of the shavings and sides of the graduator, before passing the fresh spirituous liquors through for acetification. To fill the tun, a standard liquor is taken, consisting of fifty gallons of brandy or whisky, of sixty per cent. by volume, and thirty-seven gallons of beer or malt wort. Acetification takes place slowly in the beginning; but when the shavings become gradually impregnated with mother of vinegar, the oxidation is accelerated, and the larger the amount of this body the quicker the oxidation; so that the process goes on improving. Sometimes five gallons of the above liquor are mixed with forty to fifty gallons of weak vinegar, and passed through the vessel at a temperature of 80° Fahr., and by this means the alcohol is more readily oxidized. It is well known that essential oils, or a mere trace of wood vinegar, arrest acetifying; consequently, the vinegar used must be free from pyroligneous acid. The tun, or graduator, being thus brought into a proper state of working, fifteen to twenty gallons of the standard liquor previously mentioned, are diluted with sixty gallons of soft water, and poured into the tun through the funnel in the outer cover, and permitted to pass through; it is again returned to it, unless there be several graduators in the factory, and in that case the liquor, after passing through the first, is allowed to percolate the second tub. Every succeeding hour, two and a half gallons are drawn off from the second tub, that of the first being kept as vinegar, while the

Fig. 9.



product of the second is always returned to the first vat or graduator; thus, in twenty-four hours, thirty gallons of vinegar are ready for sale. One hundred and fifty gallons of superior vinegar can be manufactured daily in ten tuns, which one man can superintend. From the purity and clearness of the product, it resembles distilled vinegar; but to make it more marketable, one pound of cream of tartar, and two pounds of brown sugar or molasses, may be added to every fifty gallons, to suit the palate of the buyers. If honey or molasses be previously added to the spirituous liquor, a vinegar of a good color is at once obtained: this addition is often made for the sake of economy. The temperature of the rooms should be at 100° Fahr., and that of the standard liquor 125° to 130° when poured in. After the working tuns have acquired a proper state for the acetification of the liquid, a temperature of 70° should be kept up in the apartments, and the charging liquid at 78° or 80°. During the time the solution is percolating, the temperature of the graduator rises to 100°—108°, from the rapid oxidation of the alcohol, as will be indicated by the thermometer as long as the operation goes on favorably. If a stronger acid be required than the product of the first and second vessels, the mode adopted is to mix the vinegar made in the first and second tuns, with a stronger alcoholic liquor, and pass the mixture through a third tub; and if, when transmitted, it should be required still stronger, a fresh quantity of alcohol is added, and submitted to a fourth tub, to obtain acid of the strength required. The vinegar procured in this way, from the first and second tuns, will require thirty to thirty-six grains of pure carbonate of potassa to neutralize every fluid ounce; that from the third tub, after being mixed with twenty gallons of the standard liquor, instead of sixteen or eighteen, will neutralize forty-five grains, and that from the fourth graduator may be made of that strength, that an ounce will saturate fifty to sixty grains of the pure alkaline carbonate.

When thick muddy liquors, or those containing much organic substance, as beers, or other mucilaginous matters, are filtered through the tuns, their dregs deposit on the chips, the accumulation of which prevents the liquid from percolating, and consequently the further oxidation of the alcohol is arrested. Should this happen, the chips are withdrawn from the graduator, washed with hot water, then steeped in hot strong vinegar, as in the forementioned instance, and returned to the tub; or a stream of hot water may be made to pass through without taking out the shavings, and afterwards hot strong vinegar, as before stated. It is better, however, always to use liquors free from sedimentary or slimy matters to charge the tuns; and if there should be any such, they ought to remain for some time in the clarifying vessel before submitting them to acetification: when these precautions are observed, the tuns will not so soon require cleansing, and the products will be purer and better. Many employ pieces of charcoal, about the size of a walnut, which have been deprived of their saline ingredients by dilute hydrochloric acid, and afterwards, of the acid, by water. The charcoal effects the oxidation of the spirit much quicker than the shavings, and it does not become so quickly choked with mother of vinegar. All those liquors spoken of in describing the *slow processes*, and indeed all alcoholic liquors free from empyreumatic products, are converted into vinegar by this method. The *wine malt* for charging the graduators is made from wheat and barley malt, mixed in the proportion of forty pounds of the former to eighty pounds of the latter; the whole well ground and saturated with forty gallons of water at 120° Fahr. After the subsidence of the solid parts, the clear supernatant liquor is drawn off, and the residuary matter washed with water at 160°, agitated, and drawn off as before; and a third affusion, in order to extract all soluble matters, is made at 200°—212° Fahr.: the whole of the washings should not exceed one hundred and ten gallons. The solution is cooled to 75°, and fifteen pounds of yeast are well comminuted with it, the whole left at rest in an atmosphere of 80° for five or six days, to undergo the vinous fermentation, after the termination of which it is ready for the graduators. Although this method is seemingly the perfection of rapid acetification in the vinegar manufacture, yet, without proper care, it is subject to its losses. In the slow methods, from the lengthy exposure to the atmosphere, a vast quantity of vinegar is evaporated and lost, even at a low temperature; much more will the elevated temperature of the graduators expel the half-converted alcohol—aldehyde—and it may happen that not a trace of acetic acid remains after the termination of the process. In the first application of the *quick* modification, this loss was very much felt, owing to the escape of aldehyde, then unknown; but on its being discovered, the chemist at once saw that the cause of the deficiency was the imperfect oxidation of this compound; and to remedy the evil, he advised an increase in the holes in the graduator, so as to admit a larger supply of atmospheric air, which proved successful. This is one of the thousands of instances of the advantages to be derived by the manufacturer having a knowledge of chemistry; and, moreover, is a happy illustration of the value of theoretic knowledge, when properly applied; for every apparently useless discovery of the theorist may, at some time or other, be made available to the perfection of the arts. The formula at page 4, expresses the change that takes place in the graduator. The formation of aldehyde may be shown by closing some of the openings which serve to supply air to the tun, and when the alcoholic liquor has passed through, by applying a solution of strong potassa to a portion of the clear liquid, we invariably obtain a brownish precipitate—aldehyde resin—which is characteristic of this body; and further, if the solution be boiled in a test tube with a little oxide of silver, decomposition ensues; part of the oxide of silver is reduced to metal, which forms a coating on the glass, and the aldehyde is converted, by uniting with the oxygen of the reduced silver, into *aldehydic* or *lampic* acid, which unites with the remaining oxide of silver, forming a soluble salt. Aldehyde boils at 70°, and at 65° its spec. grav. is 0·79; it has a peculiar ethereal odor, and is inflammable. These facts will serve to guide the manufacturer in regulating the proper circulation of air in the tuns, taking care, however, that there is not a superabundant supply, by which alcohol would be lost, from the increased temperature—110° to 120° Fahr.,—consequent on the too rapid oxidation of the spiritous liquids. Theoretically, every per cent. of alcohol by weight in a liquid should yield one and one-tenth per cent. of anhydrous acetic acid, or as much acetic acid per ounce as will neutralize five to six grains of pure carbonate of potassa. In good practice, it is found that two hundred gallons of spirit of fifty per cent. yield one thousand six hundred and sixty-seven gallons of vinegar, neutralizing thirty-two grains of the alkaline carbonate per ounce, or one thousand seven hundred and seventy-five gallons, of thirty grains neutralizing power: according to theoretical calculations, one thousand nine hundred gallons of thirty grain vinegar should be obtained, which shows a loss in practice of about six per cent. In many factories this loss is obviated, by causing the vapors from the acetifying tuns to pass over a surface of cold water, which absorbs any alcohol or aldehyde that may be evolved, and this water is afterwards used in extracting the soluble matters from fresh quantities of malt.

In some of the metropolitan establishments, a very large slightly conical tub or tun, fourteen feet wide at bottom, fifteen at top, and thirteen high, turns out as much vinegar as is in Germany obtained from six tubs, eight feet high and four feet wide. The larger mass of materials generates and maintains so much heat in the oxidation of the spirit, as to require no stove-heating in a properly constructed chamber. Two and a half feet above the bottom of this tun a false one is laid; the space over this bottom is filled with coopers' wood shavings and chips, and the room beneath is destined to receive the liquor as it trickles down on the true bottom, in order to be pumped up in continual circulation. At a moderate elevation the reservoir of the wash is placed, which discharges itself through a regulating stopcock or valve into a pipe at the bottom, which passes down through a pretty large hole in the middle of the lid of the graduator, and terminates a few inches under it in a cross pipe shut at the ends, which is made to revolve slowly by mechanical power, in a horizontal direction, round the end of the vertical pipe. This cross pipe is long enough to reach nearly to the sides of the tun, and being pierced with small holes in its under side, delivers the fermented liquor, in minute streams, equally all over the surface of the chips of wood. It thence falls into the lower part of the tun, through holes round the circumference of the false bottom, whence it is pumped up again, under certain modifications to be presently described. The air for oxygenating the alcohol into vinegar is supplied from two floating gasometers, which are made to rise and fall alternately by steam power. The ascending one draws its air from a pipe which passes into the centre of the tun, immediately under the false bottom, and, as it redescends, it discharges the air through a pipe into a cistern of water, which condenses and retains the alcohol vapor drawn off with the air. This water is used in making the next acetifying mixture. Fresh air is admitted into the top of the tun, by the sides of the vertical liquor pipe, which is somewhat smaller than the hole through which it passes. Proper valves are placed upon the pipes connected with the gasometer pump, whereby the air drawn off from the bottom compartment is prevented returning thither. A small forcing pump is employed to raise the liquor continually from the bottom of the tun to the cistern overhead. By this arrangement, good vinegar may be made in a few days without any perceptible loss of materials. The progress of the acetification in this apparatus is ascertained by testing the air for oxygen, as it is slowly drawn into the gasometers, or expelled from them. For this purpose a bundle of twine, which has been impregnated with a solution of acetate of lead, and dried, is set fire to, and plunged into a bottle filled with the air. In general, it is so well disoxygenated and carbonated that the ignition is immediately extinguished.

By regulating the warmth of the apartment, the motion of the gasometer, and the admission of air, the due progress of the acetification may be secured. The vinegar has an average strength of five and a half per cent. of hydrated acetic acid, and is immediately ready for market.—*Ure.*

Another process, not very unlike the preceding, patented by Mr. Ham of Bristol, is in operation at several works. The apparatus consists of a large vat, in the centre of which is placed a revolving pump, having two or more shoots pierced with holes, so as to cause a constant shower of wash—fermented wort—to descend from the top when they are set working. The lower part of the vat is charged with wash, the upper part with birch twigs, piled as high as possible, but without interfering with the revolution of the shoots. Between the surface of the wash and the joist which supports the birch twigs, a space of three or four inches is unoccupied, and one or more holes perforated therein, in order to admit a current of air, either direct from the atmosphere, or by means of a blowing apparatus. If the wash be maintained at a temperature between 90° or 100° Fahr., and the pump kept in continual motion, a charge may be acetified in a period of two, fifteen, twenty, thirty, or forty days, according to the quantity of liquid, and the mass of twigs through which it has to pass; but, generally, the birch twigs and liquid are so proportioned as to obtain the acid in fifteen or twenty days. The advantages offered by this modification are, that a wash made from raw grain with one-sixth of an admixture of malt, will yield a vinegar equal to that from malt alone; besides, any other liquor capable of fermentation, and producing alcohol, can be acetified as in the German process. The acetification can be arrested at any moment, and the current of air increased or diminished at will.

Messrs. Neale and Duyck, of London, patented a process for the manufacture of vinegar from beet-root, in 1841. The method given by them is the following: —The tops and shoots of the beet are cut off, and the roots, after being thoroughly washed, are rasped into a fine pulp, with which a number of strong cloth bags are filled. These bags are placed in a powerful press, with a board or hurdle between every two, and subjected to pressure till the whole of the saccharine juice is extracted from the pulp. The strength of this juice will vary from 7° to 9° of the hydrometer, and must be reduced by the addition of water to 5°, and then boiled for a short time. The liquid, or *wort*, is now removed to the coolers, in which it remains until the temperature falls to 60° Fahr. It is then conveyed to the fermenting vat, adding half a gallon of yeast to every hundred gallons of the wort. When the fermentation is ended, the fermented wash is pumped into the acidifying vessel, and is there converted into vinegar. The acidifying vessel consists of a strong vat, capable of containing twenty-four thousand gallons, in the centre of which, a short distance above the bottom, a rose, or small inverted dome, is fixed, pierced with numerous small holes, and communicating by a pipe with a blowing apparatus. Upon the bottom of the vat a steam worm lies, one end of which is connected with a steam boiler, and furnished with a steam-cock, the other end being open to the atmosphere.

The interior of the vat is divided into several compartments by means of diaphragms or perforated false bottoms, and the cover of the vat is provided with a valve which opens outwards upon a very slight pressure from within. The vat is likewise furnished with a thermometer, the bulb of which is immersed in the liquid contained in it, by which the temperature of the liquid is known.

Annexed is the mode pursued for converting the fermented wash into vinegar, by means of this apparatus:—Two thousand gallons of vinegar are first let into the vat, to serve as *mother* to an equal quantity of fermented wash, which is introduced at the same time; and a little yeast being added, the whole enters quickly into the acetous fermentation. After the action commences, air is forced into the apparatus by the blowing machine, which air, in its passage through the small holes in the false bottoms, is brought into intimate contact with the liquid, imparting to it a portion of its oxygen; the deoxidized air, and carbonic acid evolved from the vinous fermentation, being expelled through the valve in the cover, by the force of the current which is instituted through the vat. When the temperature, as indicated by the thermometer, falls below 70°, a current of steam is admitted into the worm by turning the cock, so as to maintain the heat of the vat between 70° and 80° Fahr. By this means the liquid will, in a few days, be converted into vinegar; and when that is effected, four thousand gallons more of the fermented wash are introduced, and the preceding process continued,—the whole eight thousand gallons will, in a few days, be converted into vinegar. Fresh charges are added and acetified, as just mentioned, till the vat contains twenty-four thousand gallons of vinegar; and when the acetous fermentation of the last charge has ceased, eight thousand gallons of vinegar are drawn off, and fresh wort added, and drawn off alternately, always keeping about sixteen thousand gallons of made vinegar in the vat.

Fruit Vinegar.—Apples, grapes, and other saccharine fruits, are expressed, the juice, with the addition of a little yeast, set aside in casks in a warm place—75° to 80° Fahr.—until the vinous fermentation has ceased, and then acetified by either of the preceding methods.

A very superior vinegar is made in Germany, and other continental states, from grape-sugar and the spirits produced from potatoes, beets, and molasses. The Excise laws of England, however, prevent the adoption of those materials in her manufactures, except under heavy duties.

In some factories, large quantities of sour ale and beer are converted into vinegar; but the product is much inferior to the vinegar made from wine or malt wort. The large amount of nitrogenous and other extractive matters which those liquids contain, undergoes a second or putrid fermentation after their alcohol is oxidized into acetic acid, and this quickly destroys the last traces of acid, leaving a liquid of a disagreeable odor, slightly resembling very stale beer. Sulphuric acid prevents the second fermentation for some time; still the vinegar has a nauseous odor, which renders it most objectionable.

Mr. J. C. Kent, of Upton-on-Severn, kindly informs the Editor, that when he first undertook the supervision of the manufactory of Messrs. Kent and Sons, the firm was in the habit of buying beer, ale, and porter, that had gone hard and sour, for conversion into vinegar; and on one occasion the bankrupt stock of a large brewery at Cavendish Bridge, in Derbyshire, was bought. Murmurs had reached them on several occasions that the vinegar, on being kept, lost its acidity; but when the above large quantity of beer came to be sent out as vinegar, the complaints became loud and frequent. It was found that the beer was the cause, and since that not one gallon of sour ale has been purchased by this firm. Some of the vinegar that was returned became exactly like vapid beer; it was not so putrescent as to smell, still it was a phase of the putrid fermentation. The same gentleman states, that it is impossible to make good vinegar from beer; and further, that although one or two manufacturers claim to be able to dispense with the addition of sulphuric acid to malt and grain vinegar, as mentioned further on, he has never been able to obtain a sample free from this acid.

Dr. Stenhouse, in an investigation on sea-weed, showed that when such bodies are subjected to a fermentative action, at a temperature of 96° Fahr. with lime, acetic acid is generated in large quantities, and is found, united with the alkaline earth, in the form of acetate of lime. In three experiments with different varieties of sea-weed, he obtained as a result an average quantity of one and four-fifths per cent. of anhydrous acetic acid. He employed a temperature of 96°, and added hydrate of lime, gradually, with the view of keeping the mass slightly alkaline, till the fermentation had subsided; after which the liquid was filtered off, evaporated to dryness, and the residue heated, to decompose the mucilaginous matters, when crude acetate of lime remained. No attention has yet been paid to this fact, in the production of vinegar, on a manufacturing scale, although in some of the northern countries of Europe, as well as on some of the Scottish and Irish coasts, where sea-weed is plentiful, it might prove productive. The sea-weed seems to lose nothing of its fertilizing influence on account of the fermentation.

WOOD VINEGAR, or *Pyroligneous Acid.—Holzessig*, German; *Vinaigre de Bois*, French.—This species of Vinegar, to which much attention has been lately given, is, as the name implies, obtained from wood by destruc-

tive distillation, and it is the only one of the series upon whose formation no positive data can be elicited. Caloric is the moving cause which developes the acid, when wood is subjected to its influence in close vessels. The elementary components of the wood, after a certain amount of heat is applied, arrange themselves into combinations quite distinct from those in which they were originally; some of these are gaseous, while more are liquid; but the quantity of the latter depends upon the greater or less degree of heat applied in the distillation. The uncondensed products are—carbonic acid, carbonic oxide, olefiant gas, and light carbide of hydrogen; and the condensed liquids—acetic acid, tarry and other oleaginous substances, while a residuary charcoal remains in the retort. Hypothetically, the formation of acetic acid during distillation, may be demonstrated in various ways. The composition of wood may be represented as $C_6 H_5 O_5$, two eqs. equal...... $C_{12} H_{10} O_{10}$
Minus .... $H \; O$

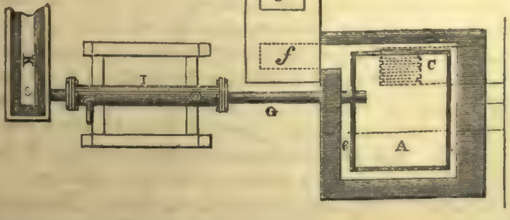
Equal three eqs. of anhydrous acetic acid, $C_{12} H_9 O_9$; consequently, it is only necessary to abstract a little oxygen and hydrogen—water—from the wood, in order to transform it into acetic acid. It may likewise be assumed that the olefiant gas evolved during the distillation, by combining with oxygen, generates the acid—

$$\underbrace{2\,(C_2 H_2)}_{\text{Olefiant gas.}} = C_4 H_4 + O_4 = C_4 H_4 O_4 = \underbrace{C_4 H_3 O_3,\ HO}_{\text{Hydrated acetic acid.}}$$

It is known that when these two gases are mixed in equal volumes, and the mixture enclosed over mercury in a bell glass, acetic acid is formed; the production of the acid, however, from the combination, requires considerable time. The facts which are observed in the actual distillation of wood are:—First, water passes off, being that which is extraneous to the wood; then, the decomposition of the wood itself gives rise to water and the acid, which is next eliminated; subsequently, condensable matters containing an excess of carbon, forming the tar and oily substance, and towards the close of the distillation, carbonic oxide and carbide of hydrogen are evolved, leaving a charcoal similar in form to the wood introduced. The distillation of wood is carried on in large cast-iron cylinders, or in square ovens made of stout sheet-iron, riveted firmly together, the heat being applied to them directly.

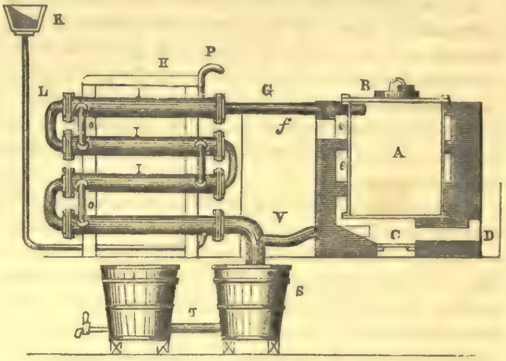
A convenient apparatus, for the distillation of wood, is annexed, of which Fig. 10 is a plan, and Fig. 11 an elevation. In these figures, A is a box made of cast-iron plates, bolted firmly, of one hundred cubic feet capacity, and imbedded in brickwork; B is a cover on the upper end of the box, through which the charge of wood is introduced, another such opening being at the opposite side—not shown in the figures—made air-tight by a cover such as B, from which the charcoal is drawn off; C, the firebars; D, the firedoor, through which the fuel is introduced; *e e*, the spiral course of the flame round the box, and *f f*, the flue passing into the chimney.

Fig. 10.



The iron pipe, G, conducts the gases, and other volatile matters evolved by the heat, to the condenser, consisting of a series of pipes, I, I, I, of a large calibre, through which the pipe, G, passes, leaving a surrounding space for cold water. The pipes rest one above the other on a wooden framework, H. Through L, a stream of water from the tank, K, enters the lower condensing pipe, and thence into the others by the connecting pipes, *o o*, till discharged by P, at a temperature reaching ebullition. The distilled vapors and gases, in their progress downwards, are partly condensed into a liquid, which falls into the air-tight tank, S, and thence by the connecting pipe, T, into another, collaterally placed, but at a lower level: V is a tube from the pipe G, projecting into the furnace, through which the uncondensed carbonaceous gases flow into the fire, where they are consumed. At first the fire is increased, and when the distillation has commenced, the gases discharged almost serve to maintain the heat sufficient to effect the decomposition of the charge.

Fig. 11.

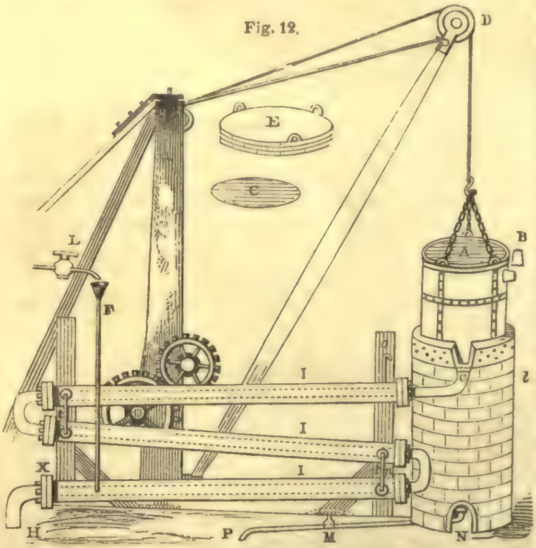


The usual time allowed for carbonizing each charge is twenty-four hours. After the wood is exhausted, the fire is withdrawn from the oven for six hours, so that the apparatus may cool, to allow the charcoal to be abstracted through the opening at the back, air-tight sheet-iron boxes being placed beneath the door to receive it. One hundred cubic feet of beechwood produce sixty per cent. of charcoal, as much brushwood being used to raise the heat required to carbonize the wood.

The apparatus in use at Nuits, and Rouen, in France, is the following:—In Fig. 12, A is a large sheet-iron cylinder, with an opening in the upper part of one of the sides, into which an adapter, B, is introduced; C is the cover of the cylinder, fitted tightly to it with bolts and screws. The cylinder being charged with wood, the cover, C, is fixed tightly in its place, and the cylinder hoisted by means of a crane, D, fixed adjacent to the furnace, and deposited in an upright cylinder of brickwork, which may be covered, at will, by means of a dome, E, made of brickwork. The cylinder being charged and deposited in its receptacle, the fire is lighted, and the tube, C, through which the distilled products pass off to the condenser, connected, and well luted to the adapter, B. The condenser is similar to that attached to the oven at Fig. 11, consisting of a series of pipes, I, I, I, through which C passes. Water from the pipe, L, enters the pipes, I, I, I, by means of F and the connecting-pipes, *t*, near the curvature, the heated water being discharged by the pipe, *o*. The condensed products pass off into the covered receiver, and a pipe, P, conducts the uncondensed gases back to the furnace, where they are consumed. The pipe, P, terminates a few inches above the ground in the ashpit, in the form of a rose, N, similar to a watering-can, in order that the flow of gases may be distributed through the fire; M is a stopcock, to regulate the quantity of gas entering the furnace.

In some factories there are different methods of condensing the products; air, in a few instances, is the medium by which the vapors are condensed. The evolved products of the distillation are made to traverse an extensive range of piping of large diameter, and in some cases the vapors are conducted through a series of casks, connected together by pipes. The most effectual mode of condensation is water, and, wherever at hand, is generally adopted. About twenty-four hours are usually allowed to work off each batch of wood.

Fig. 12.



The carbonizer of M. Schwartz is shown in Figs. 13, 14, and 15. Fig. 13 is a bird-eye view of the furnace; Fig. 14 a section of the elevation, following the lines, *d d*; and Fig. 15 another section, following the lines, C C. In the *ensemble* of these figures, the annexed objects are distinguished:—A A, the space where the wood is carbonized; *b b b b*, apertures through which the wood is introduced, and whence the charcoal is withdrawn; C C, the fires which heat the furnace; *d d*, openings through which the smoke, carbonic acid, acetic acid, oleaginous and tarry matters, pass off, through the pipes, *g g*, and thence through the condenser into the chimney; *e e* are crooked pipes, descending from *g g*, which convey the tar condensed in *g* into the vessels, *f f*—Fig. 14—the bend in the pipes, *e e*, prevents the access of air into the apparatus; H H H H are wooden canals, wherein the acid and oleaginous matters condense; I is the chimney, and *k* a small opening in the chimney, where a fire is lighted to establish a draught. The furnace walls are of fire-brick, or they may be doubly lined with brick, and the intervening space filled with aluminous earth and sand. At first the furnace is charged with the heaviest blocks of wood, and between these smaller wood is introduced, for the purpose of making the interior more permeable to the action of the fire. All the orifices of the furnace are then closed, and the fires at C C lighted, the current of air being instituted in I, as above said. The blaze of the fire traverses the furnace and carbonizes the charge of wood, and the smoke and other vapors from the furnace pass by the exit pipes, *d d*, into *g g*, whence they escape to the condensers, H H, and thence to the chimney, I. The charge is known to be completely carbonized when the smoke issuing at I, which is at first black and heavy, becomes bluish and light. The chimney passage is then closed, and the opening of the pipes, *d d*, stopped up with wooden plugs, and then well luted with some plastic clay; the firedoors are closed, and the furnace left to cool. At the end of the second day, two holes in the top of the furnace, which hitherto had been closed air-tight, are opened, and water introduced to extinguish the red-hot charcoal; the openings are

Fig. 13.

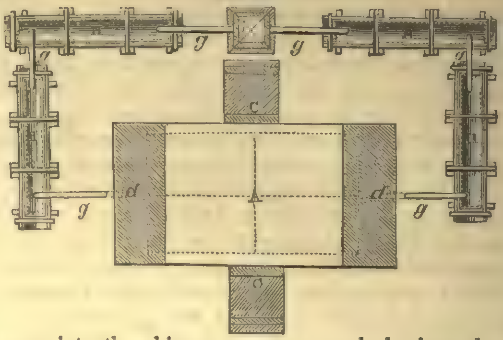


Fig. 14.

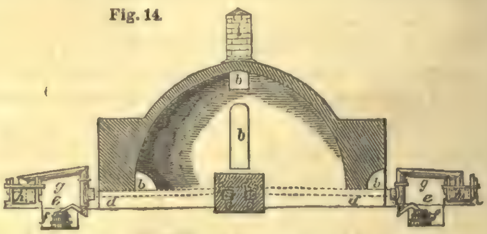
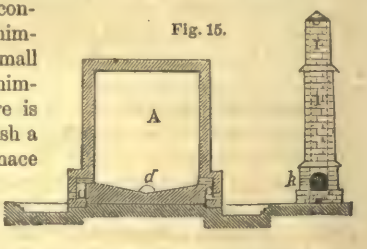


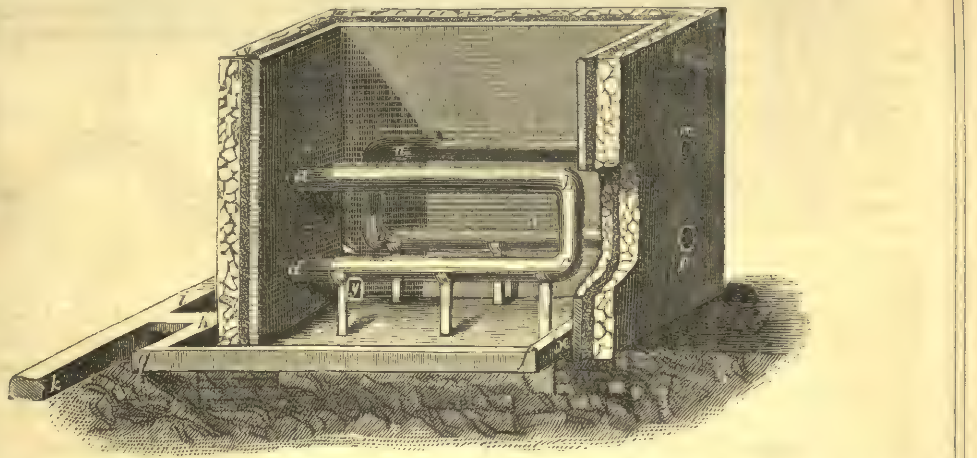
Fig. 15.



again closed for a longer period, and when the furnace gets a little colder, more water is added. If any red sparks are observed, the opening and pipes must be carefully stopped up, so as to prevent the formation of a current of air, as this would occasion the combustion of the charcoal, and consequently lessen its produce. After complete cooling, the charcoal is raked out by the apertures, *b b*, and another charge introduced. The principle of carbonization in these kinds of furnaces is different from the others already mentioned, inasmuch as the blaze from the fire never comes in contact with the wood in the latter, while in SCHWARTZ's furnace the blaze permeates the furnace entirely; but so long as a competent supply of fuel is kept on the fire, C C, no oxygen passes into the interior to consume the charcoal, and the wood is carbonized quicker. Another advantage which this furnace possesses is, that small wood may be employed to burn in C C, and the acid and other valuable products of this likewise are collected in the condensers, H H. What more particularly distinguishes SCHWARTZ's furnace above LACHABEAUSSIÉRE's is, that no air can enter it but through the fires, C C, and that there is no loss from the combustion of charcoal. The cost of this furnace is about £120, the capacity being nearly six thousand cubic feet.

REICHENBACH's carbonizing furnace consists of a square oven, made partly of firebrick and partly of ordinary bricks; the interior lining, represented in Fig. 16, is composed of the firebrick, and the outer case is of the ordinary material. The oven is heated by means of tubes, which traverse from one end of the case to the other, and are seen in *a b c d*, *m n o p*, in the figure; these tubes are from one to two feet in diameter. Heat is applied by lighting a fire in the tubes at *p* and *a*, which raises the temperature so high as to cause them to glow. The wood in the surrounding spaces of the oven abstracts the heat, and is thereby carbonized, the volatile products of which pass off at the bottom of the oven, through the openings at *x*, into the canal, *f g h*, and through *y*, at the opposite side, into a similar canal: both products intermix in the canal, *k i*, where the tar is partly deposited. From the tube, *k i*, the acetic acid vapors are carried off to the condenser, as in the ordinary process of the manufacture.

Fig. 16.



The chief pyroligneous acid factories in England are in the counties of Gloucester, Northumberland, Lancaster, and Monmouth; and one in Glamorganshire in Wales. Cylinders of varied length, from six to ten feet, and two and a half to four feet in breadth, are

Fig. 17.

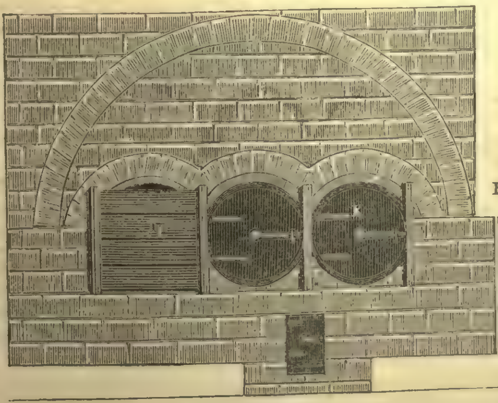
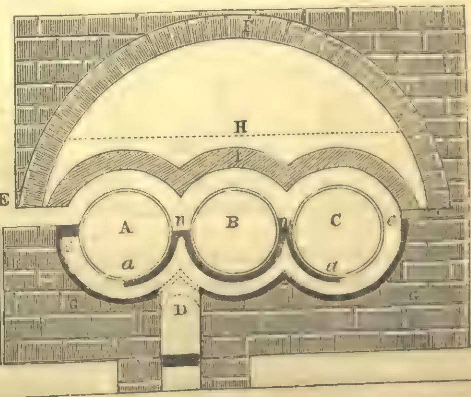


Fig. 1



employed. These are placed horizontally in brickwork domes, the front and back ends being closed by doors which swing on stout hinges, or by plates screwed firmly to these openings. A pipe issuing near the convex extremity of the further end of the retort, carries off the gases and condensable products to the refrigerator. A general view of the retorts and condenser is seen in Figs. 17 to 22. Fig. 18 presents a section of cylinders, A, B, and C; and in Fig. 17 is seen their position enclosed in brickwork, with the doors, K, closed. The fire is at D, Fig. 18, and the space, *e e*, shows the course of the flue round the cylinders, till it reaches the chimney, E. The passage of this flue is more clearly seen in the plan, Fig. 20, where the dotted lines, *d d*, *et cetera*, are the circuits it makes. The space, A, B and C, indicates the cylinders and the pipes attached to them for conducting the distilled products to the tank, D, where most of the tar is deposited, and the partly depurated product issues through a small pipe into a condensing tube. This is more perspicuously seen in the elevation of the cylinder and tank, as shown in Fig. 21. Fig. 22 is a section of the tank where the tar is deposited; the tank is protected by a cover, which fits into the enlarged part or groove at the top of the sides of the tank, acting as a water lute, as is seen at *h*. The pipe, *i*, carries off the acetic acid vapors to the serpentine pipe in the large tub, C, which it enters at *k*, in the figure. Beneath the tank, A, a tub, *n*, is placed; both are connected by *m*, that enters at the bottom of the tank. The tarry matter, as it accumulates in the tank, falls through the pipe, *m*, into the tub, *n*. F is a tub placed below the condenser, C, where the acid is collected, and the uncondensed gases pass off through the pipe, D, and are consumed at *l*, so as not to corrupt the air in the factory. The arc, B, Fig. 22, shows the position of the condensing vessel with regard to the cylinders, it being the same as F in Fig. 18. The space at H may be used as a torrefying chamber when preparing the acetates, described at page 46. Sometimes two of these cylinders, placed in the same dome of brickwork, are heated by one fire, the flue playing round each, as in Fig. 23, where *a a* are the cylinders; *f f f* the fires; *c c c*, ash-pits, and *o o o* the course of the flue to the chimney. Even five such carbonizers, placed in one arch, are heated by

Fig. 19.

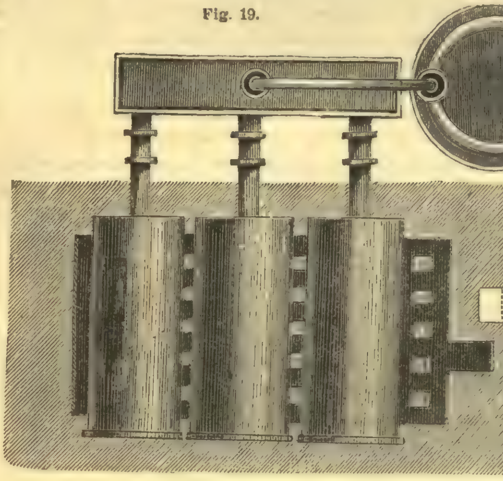


Fig. 20.

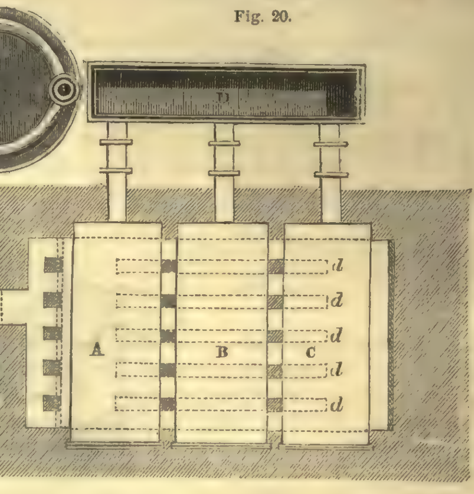


Fig. 21.

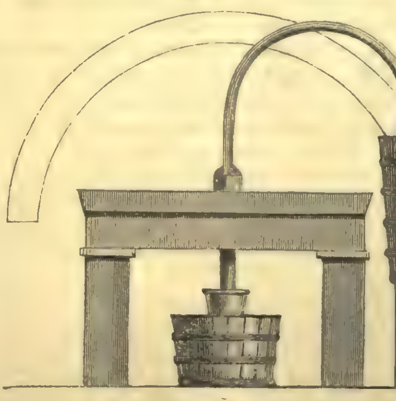
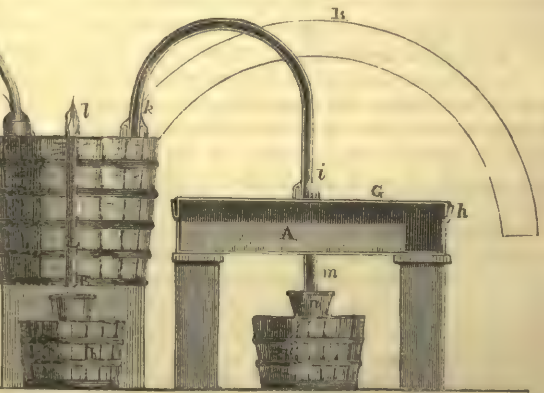
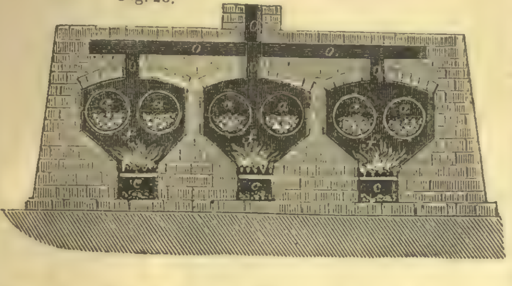


Fig. 22.



two fires. Such is the arrangement at Pitchcombe Chemical Works, near Stroud, Gloucestershire, where the cylinders are nine feet by two feet ten inches; thirteen of which are capable of holding five and a half *cords* of wood, each cord being sixteen feet eight inches in length, and two feet two inches in breadth, and the same in depth, the weight of which, according to the state of freshness or otherwise of the wood, is between twenty-three and twenty-five hundreds. One ton and a half of coal serve to carbonize the whole. The usual time allowed to carbonize each charge is twenty-four hours. Factories which are carried on at Risca and Abercarn, in Monmouthshire, by the same proprietor, form conjointly the largest in the kingdom. In the Risca Works, cast-iron cylinders, six feet long by four feet in diameter, are used, each being capable of holding about two tons of wood, or three-fourths of a cord. Wrought-iron chests are likewise serviceable, having an iron pipe six inches diameter passing up through the centre of the chest, in order to convey the heat to the interior. Each chest is capable of holding a cord and a quarter of wood—one hundred and sixty cubic feet, a cord of wood being one hundred and twenty-eight cubic feet—which weighs about three tons and a half. At Abercarn, eight square ovens, with boxes, are the variety of carbonizers, each oven being capable of holding one cord of wood—one hundred and twenty-eight cubic feet. Twenty-four hours is the time usually allowed to work off each charge, but if the demand for the distilled products be urgent, the charge may be exhausted in sixteen to eighteen hours. In this case, the products are not so much as when the distillation is carried on slowly.

Fig. 25.



At Cornbrook Works, near Manchester, the cast-iron cylinders are six feet long by three feet diameter, with square doors, which hang on stout hinges. Generally, six tons of wood are carbonized by one and a half ton of coal; one fire being made to heat two such cylinders, placed adjacent to each other in the same arch.

At Breeme, near Lidney, in the forest of Dean, there are eight large square ovens, each capable of containing two sheet-iron boxes, four feet six inches by two feet nine inches in interior measurement. In each of these boxes about half a cord of wood is placed, and as the wood is piled up above the top of the sheet-iron box, the ovens are required to be of a size proportioned to this height. The doors of the ovens are on hinges, fastened and luted, when the charges are enclosed in the usual manner. These ovens are charged once a day; but as the wood is light, twenty-four hours are more than sufficient to effect its carbonization. The boxes, when charged, are run along a railroad into the ovens, and withdrawn in a similar manner, whereby much labor is saved.

At Lougher, near Swansea, they use a peculiar sort of apparatus—a large sheet-iron carbonizer, divided internally into six compartments, into which six sheet-iron vessels, of four feet in height and two feet broad, fit; the whole forming a cylindrical shape similar to the outer case. There is only one opening in the top of the carbonizer, through which the vessels containing the wood are introduced; but there is a movable framework in the bottom of the outer vessel, by means of which each receptacle is brought directly under the orifice, and the charged box lowered into it by a crane. When charged, this aperture is closed by a sheet-iron door and firmly bolted, then luted in the ordinary way, and heat applied. The sheet-iron case is imbedded in brickwork, and the fire directly under it, the flue rising spirally about the carbonizer. A similar apparatus to this is in use at Deptford.

Upon a comparison of all the modifications of carbonizing retorts sketched, it will be evident that the cylinders are more adapted for the distillation of the large billets, or heavy cord wood of Gloucestershire, and the refuse ship-timber of Glasgow, Newcastle, and Liverpool.

The most economical are cylinders between eight and ten feet in length, and from two and a half to three feet in diameter. On the contrary, where light wood is used, such as that generally carbonized in the Welsh factories, the square ovens suit better; however, as the supply of wood is always subject to variation as to its bulk, it is more satisfactory to have both forms of apparatus on the premises. From the cylinders, the charcoal is generally raked out at the door at the opposite end, into sheet-iron boxes, or square pits sunk in the floor, and lined with firebrick; the chests and pits are capable of being perfectly closed.

In many factories, the charcoal is abstracted from the carbonizing cylinders by means of the following apparatus:—An iron shield, almost the size of the interior of the cylinder, is placed near the mouth of the retort, to which a chain is attached, that runs through the whole length of the carbonizer. The workman, by seizing this chain with a suitable implement, draws out the whole of the charcoal nearly all at once, and with less risk of breaking it than when the rakes are employed.

The relative amount of charcoal, as well as the gaseous and liquid products, depends on the species of wood subjected to distillation, as also upon the regulation of the proper heat to effect the same. The temperature should at first be gentle, gradually increasing in proportion to the time, till towards the end it approaches an incipient red heat, in order to dissipate all the volatile products from the wood. The strongest acid is generally obtained from timber of slow growth on dry soils; next from timber grown on moist ground; and lastly, from pines and resinous trees. The productions of the latter variety are not, however, so inferior as generally stated, when proper attention has been paid to the regulation of temperature, and complete carbonization of the charges. This will be seen under the distillation of spent dyewoods, sawdust, *et cetera*, as carried on with success by Mr. A. P. **Halliday**, of Salford, whose apparatus is there represented.

The following tabular view of the amount and strength of the products obtained from the distillation of several varieties of wood, is taken from the work of **Stolze**. The quantity of the varieties of wood submitted to destructive distillation was *one pound*, a quantity which will, in the generality of cases, form a precedent for the manufacturer on the large scale:—

One Pound of Wood.		Weight of Acid.	One ounce of Acid neutralized of pure Carbonate of Potassa.	Weight of Empyreumatic Oil.	Weight of Charcoal.
	Botanical Names.	Ounces.	Grains.	Ounces.	Ounces.
White Birch	Betula Alba	7⅛	55	1⅜	3⅞
Red Beech	Fagus Sylvatica	7	54	1⅕	3⅕
Large-leaved Linden	Tilia Plataphylla	6⅞	52	1⅞	3⅜
Oak	Quercus Robur	6⅛	50	1⅛	4⅛
Common Ash	Fraxinus Excelsior	7¼	44	1⅜	3¾
Horse Chestnut	Esculus Hippocastanum	7⅜	41	1⅜	3¼
Lombardy Poplar	Populus Dilatata	7⅜	40	1⅜	3¾
White Poplar	Populus Alba—abele	7⅜	39	1¼	3¾
Bird Cherry	Prunus Padus	7	37	1¼	3⅓
Basket Willow	Salix	7⅜	35	1⅛	3½
Buckthorn	Rhamnus	7⅓	34	1⅜	3½
Logwood	Hematoxylon Campechianum	7⅛	35	1½	2
Alder	Alnus	7⅜	30	1⅛	3½
Juniper	Juniperus Communis	7¼	29	1¾	3⅜
White Fir	Pinus Abies	6⅜	29	2⅛	3⅜
Common Pine	Pinus Sylvestris	6¾	28	1⅕	3⅛
Common Savine	Juniperus Sabina	7	27	1⅞	3⅜
Red Fir	Abies Pectinata	6⅜	25	2¼	3¾

Eighty-four Pounds of Wood.	Charcoal.	Charcoal per cwt. of Wood.	Acid liquor.	Sp. gr. of Acid liquor.	Sp. gr. of Acid liquor saturated with Lime.	Measures of Soda to neutralize Acid liquor.	Incondensable products.	Real Acid.
Birch,	23⅓	31·33	45	1·046	1·080	70	15	1·86
Elm,	21½	28·66	45½	1·036	1·075	83	17½	2·26
Willow,	18	24·00	49	1·029	1·045	29	17	0·77
Beech, low temp.	24	32·00	46	1·039	1·090	115	14	3·06
Do. high temp.	20	26·64	47	1·034	1·067	90	17	2·40
Laburnum,	20	26·64	46	1·030	1·055	75	18	2·00
Ash,	23	30·68	48	1·035	1·078	92	13	2·45
Alder,	20	26·64	48	1·030	1·065	70	16	1·86
Hawthorn,	20	26·64	27	1·040	1·100	140	37	3·73
Young Oak,	28	37·33	39	1·038	1·085	115	14	3 06

Three hundred and thirty-six Pounds of Wood.	Charcoal.	Charcoal per cwt. of Wood.	Acid liquor.	Sp. gr. of Acid liquor.	One ounce neutralized grs. of Bicarbonate of Potassa.	Dry Acetate of Lime produced.
Beech,	84	28·00	180	1·029	9½	25
Walnut	72	24·00	150	1·018	7	14½
Birch, cut three years	70	23·33	120	1·031	11	13
Oak,	91	30·33	190	1·022	8	24
Ash,	90	30·00	190	1·024	8	22
Apple,	70	23·33	200	1·017	6	18
Wych Elm,	70	23·33	180	1·018	8	16
Maple,	77	25·66	145	1 018	6	20

The *ensemble* of three works in the neighborhood of Paris showed the following products from four thousand pounds of wood—beech and oak:—

Charcoal, 1,014 lbs.
Acid Liquor, 2,335 " sp. gr. 1·027 = 416 lbs. of dry [acetate of lime.
Tar, 330 "

The following products were obtained at the works of M. **Mollerat**, at Nuits, from 1,000 steres of wood, weighing 5,120 cwt.:—

Charcoal,	1,280 cwt.
Pyroligneous acid,	850 "
Acetic acid,	54 "
Acetate of lead,	152 "

In a well-conducted establishment in England, the annexed were the quantities of crude acid liquor obtained by the distillation of 1,634 cords of wood; each cord of wood weighing 512 cwt., according to the longer or shorter time allowed to intervene between the cutting and the using of the wood:—

174	cords produced	23,923	gallons of about 10 lbs. each.
160	.. ..	27,720	.. .. ..
252	. ..	30,424	.. .. ..
318	.. ..	40,584	.. .. ..
330	.. ..	55,900	.. .. ..
400	.. ..	50,700	.. .. ..

The subjoined is one of the monthly statements of works in the vicinity of Paris, in which the wood is carbonized by heat from the coke ovens:—

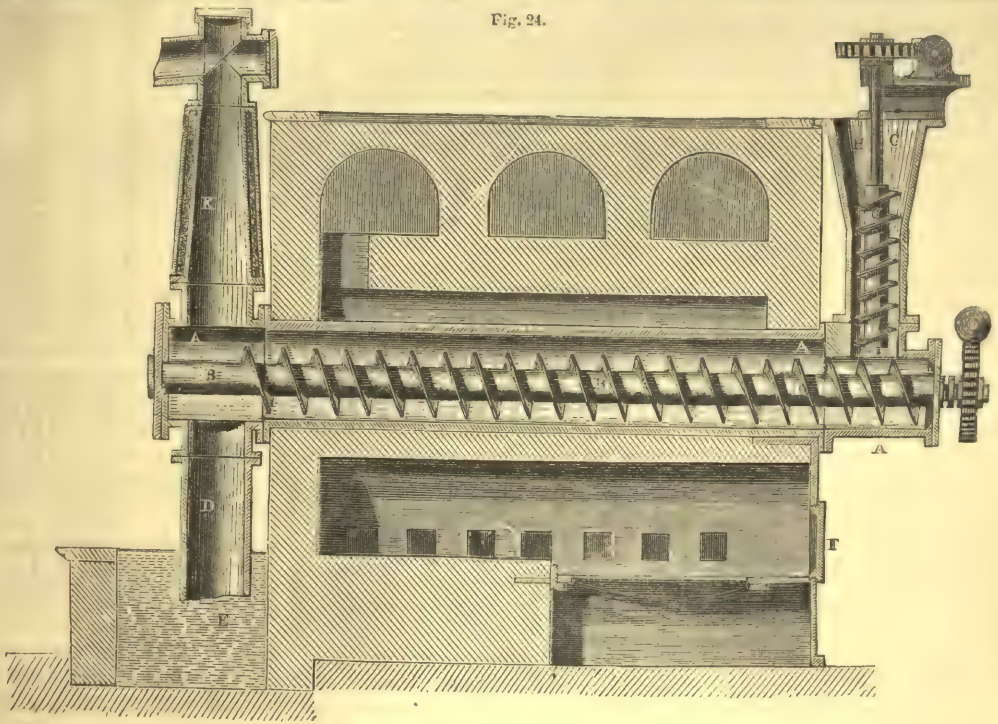
Dr.	frs.	c.	Cr.	frs.	c.
1,000 Hectolitres of coal, at 50 frs. the 15 hecto.,	3,333	33	1,520 Hectolitres of coke, at 49 fr. the hecto.,	4,312	00
500 Steres, half cords, of wood, at 9 fr. 20 c.	4,600	00	30 Hectolitres small coke, at 32 fr. 50 c.	975	00
Wages of coke-oven man,	120	00	750 Loads of charcoal, at 6 fr.,	4,500	00
Wages of six workmen,	450	00	150 do., second quality, 5 fr.,	750	00
Wages and lodging of two carmen,	200	00	50 do., third quality, 4 fr.,	200	00
Keep of two horses,	180	00	20 do., powder, 2 fr. 50 c.	62	50
Salary of director of works,	200	00	200 Casks pyroligneous acid, at 15 fr.	3,000	00
Wear and tear, calculated at ten per cent. on the value of the plant—60,000 frs.	500	00	Tar,	165	00
Five per cent. interest on capital,	416	00			
Rent of ground and cellars for charcoal,	100	00			
Frs.	10,099	33	Frs.	13,964	50

One franc equals ten pence English; one hundred centimes are equivalent to a franc. The French hectolitre is a measure of capacity, containing one hundred litres, equal 22·009668 imperial gallons; 4·5434579 litres equal an imperial gallon.

Mr. A. P. **Halliday**, of Salford, has obtained a patent for the manufacture of pyroligneous acid, *et cetera*, from sawdust, spent bark from tanyards, and dyewoods exhausted of their coloring matters, which is in operation at the works of Messrs. **Hervey, Peak**, and **Hervey**, the largest and most eminent manufacturers of decoctions in this kingdom; at the works of Messrs. **Hadfield** and **Renney**; and at Messrs. **Halliday, Pochin**, and Co. For a long time the distillation of sawdust was unsuccessfully attempted, the apparatus used being applicable to the decomposition of the material; for on being introduced into either the ovens or cylinders, a layer of carbonized sawdust coated the retort so effectually, when the temperature was raised, that the further progress of the decomposition was arrested by the non-conducting property of this hard layer of minutely divided charcoal.

Fig. 24 is a drawing of the apparatus patented by Mr. **Halliday**, by which the preceding obstacle is overcome. The sawdust, spent dyewood, *et cetera*, are introduced into a hopper, H, placed above the front end of an ordinary cylinder, A A, in which a vertical screw or worm, C, revolves, conveying the material, and in the proper quantities, to the cylinder, placed in a horizontal position, and heated by means of a furnace, F. Another revolving screw or worm, B B, keeps the material introduced into the retort by C in constant agitation, and at the same time, moves it forward to the end. During its progress through the retort, the materials are completely carbonized, and all the volatile products disengaged. Two pipes branch off from the ulterior part of the retort, one, D, passing downwards and dipping into an air-tight vessel of cast-iron, or a cistern of water, E, into which the carbonized substance falls; the other ascending pipe, K, carries off the volatile products of the distillation into the condenser, consisting of pipes of copper or iron, immersed in or surrounded by water. Messrs. **Hervey** and Co. convert all the spent dyewoods of their manufactory into pyroligneous acid, and the charcoal obtained, when ground finely, answers well for steel manufacturers and iron founders.

Fig. 24.



The quantity of acid obtained from spent dyewoods, equals the amount usually derived in the ordinary distillation of wood. Messrs. **Hadfield** and Co., and Messrs. **Halliday** and Co., use sawdust, the produce from which is found greatly at variance with the statements set forth in chemical and manufacturing works—that *pine* and such resinous woods yield comparatively very little acid. Practically, eight retorts of the above description, fourteen inches diameter, produce as much pyroligneous acid in twenty-four hours, as sixteen retorts, three feet in diameter, during the same time, yield when worked on the old system. The charcoal from sawdust is extensively used as an ingredient of artificial manure, and many printers use it as an absorbent in the urinals attached to their factories. Charcoal being an excellent disinfectant, the nuisance that would arise from such cisterns is completely abated. Moreover, the Messrs. **Hargreaves**, of Accrington, state, that when the charcoal is saturated, the effluvia is taken away, and the ammonia, *et cetera*, arising from the decomposition of the nitrogenous compounds of the urine, are retained, so that it offers a ready and economical means of transferring these fertilizers to the soil.

The average produce from eight retorts, taken for many weeks, carbonizing twenty-two tons of sawdust weekly, is the following:

Pyroligneous acid 10° Twaddle = 1·05,	2484 gallons.
Tar,	240 "

to which, by way of comparison, is subjoined the average yield per ton of oak, when carbonized in the ordinary cylinders.

Weight of wood,		2240 lbs.
" pyroligneous acid,	1277 lbs.	
" charcoal,	600 "	
		1877 "
Loss—uncondensable gases,		363 "

According to the state of dryness of the wood when submitted to the retorts, the products are a little more or less; but generally the range of produce is between one hundred and twenty-four and one hundred and twenty-seven gallons of 6° Twaddle, or 1·03 spec. grav., and six hundred pounds of charcoal. From the preceding, it is evident that the same quantity is obtained from the sawdust, and of a far higher specific gravity.

The average price of oak wood is eighteen to twenty shillings per ton, and for cutting this in convenient billets for the retorts, *et cetera*, the cost is usually about two shillings to two and sixpence. About seven hundred-weight of coals are found sufficient to carbonize one ton of wood. The tar obtained in distilling pine wood saw-dust is of equal quality to that imported.

In the vicinity of Manchester, where exhausted dye-woods and sawdust are plentiful, a decided advantage in the yield and quality of the products is to be gained by operating upon those materials.

Messrs. Solomons and Azulay patented a process, the main feature in which was the transmission of steam heated to a high temperature through the mass of material. By this method, every particle is exposed to the superheated steam, and completely carbonized. The charcoal left is well adapted for manuring purposes; besides, we have all the products ordinarily obtained in the ligneous distillation. The steam accompanying the other products renders them dilute; these vapors are, however, made subservient in concentrating the condensed products as they pass to the condenser; for they are made to traverse a coil of piping placed in a pan of the distillates. If this had not been suggested by a chemist, the patent could never be advantageously worked. The heated steam prevents the deposit of tarry and other resinous matters; consequently, no choking of the pipe need be apprehended.

The following brief sketch of the pyroligneous acid manufacture, has been transmitted to the Editor by Mr. John Randall, the manager of the Pitchcoombe Works at Stroud, and who has been there since their commencement in 1842.

Mr. Randall states:—It remains still a disputed point whether small or large retorts are preferable. After a trial of different sizes, and some years' experience, he considers a retort of moderate dimensions the most convenient and serviceable. Those in use here are nine feet and a half in length, and two feet and a half in diameter, enclosed in brickwork, and placed horizontally, three or five in a set.

They are secured in front by lids, fastened by means of a cross bar. At the back there is an exit pipe, eight inches in diameter, connected with a main pipe. From this the liquor is conducted by a series of pipes, immersed in water, into a large tank. Retorts set in the method described are heated more economically, and the charcoal is good.

Each retort holds about half a cord of wood, which, when of beech, of the average dryness, weighs about twelve hundred-weight. These retorts are charged once in twenty-four hours. As to the quantity of liquor produced from a given weight of wood, of course much depends on the condition of the wood, whether green or dry—that which has been cut down about six months is the best for practical purposes, the liquor being stronger in acid. A cord of wood in this state yields from one hundred and twenty to one hundred and thirty gallons of liquor, *id est*, acid, water, naphtha, and tar, leaving in the retort, charcoal, about one-fifth of the weight of the wood originally employed. The next process is to separate these various products, and for this purpose the liquor is pumped up into copper stills, and, for safety, steam heat is applied. Naphtha, in a weak and impure state, comes over first, then the pyroligneous acid, leaving a tarry residuum in the retort. Some manufacturers prefer adding lime to the liquor in the tank, before it is transferred to the stills: this, perhaps, is best for the production of naphtha, but it involves the necessity of making black or brown acetate of lime, which, from its inferior quality, is often difficult of sale, unless at a low price.

After distillation, the acid is removed to large tubs or vats, and neutralized with lime. It is then allowed to stand for a few hours, and the clear solution siphoned off into evaporating pans. The vessels used here for this purpose are made of wrought-iron, of an oblong shape, about nine feet in length, four feet in width, and two feet in depth; they contain about four hundred and fifty gallons. The solution is boiled down to a proper consistency, put into draining buckets, and then removed to a drying stove. This is the ordinary process; but when the acetate is required of superior quality, the solution should be properly evaporated, then allowed to stand for eight or ten hours, carefully drained off from its sediment, and boiled to its crystallizing point. Simple distillation, though it separates a large portion of tarry matter, never renders the pyroligneous acid pure; this can only be effected by neutralizing the acid with carbonate of soda, evaporating the solution to dryness, and then subjecting the exsiccated mass to fusion. The *black cake*, as it is termed, is redissolved, boiled to the crystallizing point, and drawn out into large shallow vessels to deposit the salt.

The trade has been in a depressed state for the last few years; and, indeed, it is liable to such fluctuations that there is not sufficient inducement for a capitalist to embark in it.—*Randall.*

M. Paur has recently published a method which he follows in the preparation of acetic acid, and the acetates from the product of the distillation of wood, by which he dispenses with the labor of distillation, evaporation, and for the most part the torrefaction attendant upon the processes generally pursued in this branch of the manufacture.

His method consists in presenting to the vapor of acetic acid, during the operation of the carbonization, a substance which seizes exclusively upon it, and thereby concentrates it.

The bodies which will the most readily satisfy this condition, are those bases whose acetates are not decomposable at the temperature of the operation; such as potassa, soda, baryta, lime, magnesia, *et cetera;* and the carbonates of these same bases, or any other salt whose acid can be displaced by the acetic acid. The author gives the preference, according to locality, to lime, a calcareous carbonate, magnesian carbonate, or carbonate of soda; the first three, because of their low price; the last, because it will yield directly the acetate of soda,—a product prepared at a future stage for the entire purification of the acid.

This process may be applied, whatever be the mode of the carbonization. The manner in which it is adapted to carbonization *en meules*—piles or masses of rough wood covered with earth—will now be described.

It is well known that carbonization *en meules* is effected by the heat produced by means of the combustion of a certain quantity of the wood of the pile, when ignited. Orifices left at the foot of the pile give access to the air necessary for combustion; others pierced at different heights and in different positions, by the workman charged with directing the progress of the carbonization, serve for the escape of the products of combustion and distillation. In these last orifices, at the point where the workman has judged it necessary to carry the draught, M. PAUR introduces tubes into the earth of about an inch interior diameter, and half an inch in thickness, which, dividing over all the pile, terminate in bundles, in numerous recipients distributed quite round the mass. These pipes may be composed of several ends or short pieces, connected by jointings, so that, when the progress of the carbonization requires the displacement of the orifices for the emission of the smoke, the extremity only of the tubes may be removed, without the necessity of deranging the receivers.

The latter are simple casks, of fourteen inches diameter, and three feet and a quarter in height, into which the tubes lead by one extremity, and which are filled, in whole or in part, with pieces of lime, carbonate of lime, or carbonate of soda, divided into fragments varying in size according to the state of porosity of the matter, and leaving between them interstices, which permit the passage of the vapors.

Acetic acid and the other products which escape from the wood, are conducted by the pipes to one of the extremities of the cask, and traverse the different layers of carbonates or of lime, which fix the acetic acid, whilst the other products escape at the other extremity of the receiver.

It is proper to remark, that this process presents one advantage over that by refrigeration; namely, that considering the temperature maintained in the interior of the casks, much less tar is condensed, which renders more easy the subsequent purification of the acid.

The acetate of lime obtained in this manner, may be submitted to the same operations as in the processes at present in use.

It would be possible, under certain circumstances, in place of particular receivers, to introduce into the midst of the pile, in the intervals left between the logs, the substance intended to unite with the acetic acid.

There are some factories which expressly distil the wood in close vessels to obtain the acetic acid. For these, the method described would still have great advantages. In fact, there would be nothing to prevent so regulating the temperature of carbonization, that the acetate of soda produced in the apparatus should not itself be decomposed, while leaving this temperature sufficiently high to destroy or expel the tar, in such a manner that the torrefaction would be combined with the carbonization, so as to obtain, at one operation, a concentrated and purified body.

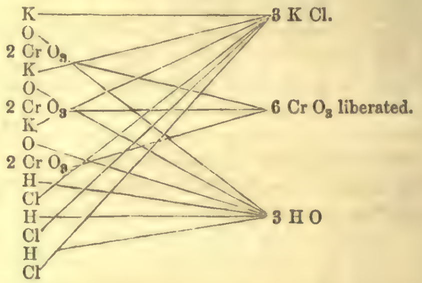
PYROXYLIC SPIRIT, or WOOD NAPHTHA.—PURIFICATION OF THE PRODUCTS OF DISTILLATION.—The distillates of wood are received in a tank or some suitable vessel, and on allowing the whole to rest for some time, the excess of tarry and other resinous and oily matters precipitates, the spirit and acid liquor forming a supernatant layer, which may be drawn off into another tank by means of an overflow pipe or siphon. If the liquids, in their passage from the first tank, be made to percolate a filter of coarse gravel, a large quantity of the matters held in suspension by the acid liquor is separated. The purification of the spiritous and acid products is effected in two ways: first, where the spirit is distilled directly from the crude liquor, and secondly, where the acid is neutralized with milk of lime, and then submitted to distillation to obtain the spirit. In the first instance, copper stills of about five hundred gallons capacity are used, into which the liquor is pumped, and heat applied by means of coils of copper pipe placed in the interior of the stills, through which steam from an adjacent steam-boiler is forced; in other cases the heat is applied externally, either by steam-pipes coiling round the still, or by the direct application of fire. The distillation is continued till all the spirit has passed over, which is known by throwing a portion of the distillate on a bright fire—the spirit inflames, giving a whitish light.

In most instances, the whole of the naphtha is expelled when about one hundred gallons are condensed in the receiver. When there are no more vapors eliminated, the receiver is changed, and the distillation of the acid liquor proceeded with till all the liquid has nearly passed over, the tarry and oleaginous products remaining being run off through a stopcock in the bottom of the still into a tank. Should the acid be not directly wanted, after the expulsion of the spirit, the remaining four hundred gallons may be drawn off into the tank, and allowed to rest, so as to deposit the excess of impurities, and afterwards pumped up to other vessels when required. Some manufacturers first neutralize the acid liquor by means of hydrate of lime, and afterwards distil the spiritous and crude acetate of lime liquors in sheet-iron stills or boilers to obtain the naphtha. Fire is applied directly to the under part of the boiler. The remaining acetate of lime liquor is drawn off, and allowed to remain in tanks or reservoirs till required for use. The deposit of tarry matters which accumulates in the first receiver of the condensing apparatus, attached to the wood carbonizers, is also submitted to distillation, and the crude spirit therefrom added to former portions.

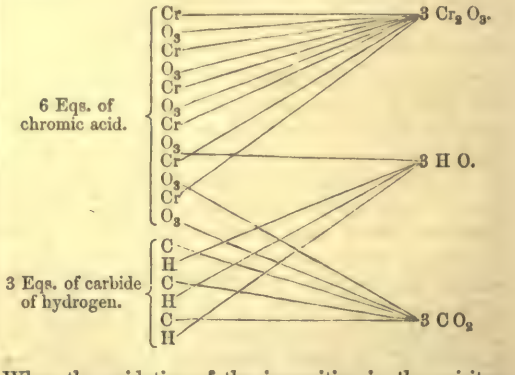
The further purification of the crude spirit obtained in the preceding distillation, is effected by repeated rectifications, over caustic lime at first, and then over a mixture of lime and caustic potassa; and, in order to detach the small quantity of ammonia that is formed, the final distillation of the product is carried on with a little sulphuric acid. In some factories they rectify the distillates over chalk, and in some others over chalk and bicarbonate of soda. Copper stills are those which are used, and the heat applied, either by steam pipes, coiled in the interior of the still, or the lower half of the retort may be incased in an iron jacket, to which the fire is directly applied.

The spirit thus obtained is colorless, and varies in specific gravity from ·870 to ·832. A few years ago, Mr. Wildsmith obtained a patent for the februation of the spiritous and acid products of the distillation of wood. The principle of his invention is the application of an oxidizing agent, together with the influence of light, by which treatment he purposes to oxidize the carbides of hydrogen, which are unessential to the spirit and acid, but whose presence communicates a disagreeable odor to the products. Bichromate and hypermanganate of potassa are the salts generally employed, in the following manner:—The liquors are placed in a tank secluded from the air or the accidental admixture with dirt, or other impurities, by means of a cover, in which a part is glass, or some other transparent body—mica, so as to admit the light, which is necessary for the success of this application. Four ounces, avoirdupois, of the forementioned compounds, in fine powder, are used to every imperial gallon of the liquid; this may be thrown into the tank with the liquid, or the salt may be dropped into the solution gradually, and the whole well agitated. The time required to effect the purification of the spirit depends upon the quantity of tarry matters present; but, in ordinary cases, from fourteen to twenty-one days will suffice. Sunny weather favors the purification of the spirit and acid from the foreign compounds, as it brings about the combination of the oxygen of the oxidizing agent with the carbonaceous impurities in a very considerable measure. Other compounds, such as peroxide of manganese, or a properly regulated stream of chlorine gas passed through the solution, might answer the purpose, but the hypermanganate and bichromate of potassa or soda offer the greatest facilities in their use; besides, they are, by effecting the intended purpose, converted into bodies which exert no diminishing action upon the substances sought, and which may be easily separated from the spiritous and acid liquor by distillation. Chlorate of potassa might be successfully employed in the purification; it is, however, a much dearer salt than those mentioned by Wildsmith, and perhaps for that reason it is not used. When the purifying reagents have been added, the fluid should be agitated once or twice daily, in order to bring the solution of the salts into immediate contact with the impure liquor: during the intervals the cover should be kept on. Frames of glass or mica in the cover are made to slide backwards and forwards, in order to allow the liquid to be examined, and learn how far the purification has advanced. If it be desired to hasten the februation, sulphuric or hydrochloric acid is added, in the proportion of one pound of acid to fifty gallons of spirit. The object of such additions is to liberate more freely the acid in combination with the potassa, and thus bring the whole of the oxygen within reach of the carbides of hydrogen, and the other analogous impurities;

3 Eqs. of bichromate of potassa, when decomposed by
3 Eqs. of hydrochloric acid, give
3 Eqs. of chloride of potassium, while
6 Eqs. of chromic acid are liberated; thus,



The chromic acid, coming in contact with the carbide of hydrogen, gives off oxygen freely, being itself reduced to the state of sesquioxide of chromium—Cr_2O_3—thus:



When the oxidation of the impurities in the spiritous liquor is completed, it is submitted to distillation in the usual way, and a clear colorless product, without smell, and capable of being burned in lamps, or for any other required purpose, is obtained. The general yield of spirit is from one gallon and a quarter to two and a half gallons, and rarely three gallons, per the ton of wood. This variation in quantity is due often to the kind of wood carbonized, but more frequently to inattentions in regulating the proper degree of heat.

The subjoined is a tabular view of the per centage amounts of spirit in naphthas of different specific gravities, drawn up by Dr. Ure. The spirit operated upon in these experiments was purified by distillation over quicklime, at the heat of a water-bath, the temperature being so regulated that the liquid had a density of ·8136 at 60° Fahr.

Sp. gr.	Real Spirit, per cent.	Over Excise proof.	Sp. gr.	Real Spirit, per cent.	Over Excise proof.
·8136	100·00	. .	·9032	68·50	13·10
8216	98·00	64·10	9060	67·56	11·40
8256	96·11	61·10	9070	66·66	9·30
8320	94·34	58·00	9116	65·00	7·10
8384	92·22	55·50	9154	63·30	4·20
8418	90·90	52·50	9184	61·73	2·10
8470	89·30	49·70			Underproof.
8514	87·72	47·40	9218	60·24	0·60
8564	86·20	46·60	9242	58·82	2·50
8596	84·75	42·20	9266	57·73	4·00
8642	83·33	39·90	9296	56·18	7·00
8674	82·00	37·10	9344	53·70	11·00
8712	80·64	35·00	9386	51·54	15·30
8742	79·36	32·70	9414	50·00	17·80
8784	78·13	30·00	9448	47·62	20·80
8820	77·00	27·90	9484	46·00	25·10
8842	75·76	26·00	9518	43·48	28·80
8876	74·63	24·30	9540	41·66	31·90
8918	73·53	22·20	9564	40·00	34·20
8930	72·46	20·60	9584	38·46	35·60
8950	71·43	18·30	9600	37·11	38·10
8984	70·42	16·16	9620	35·71	40·60
9008	69·44	15·30			

M. **DEVILLE** has likewise completed a table, showing the quantity of real spirit in naphtha of different specific gravities, at 48·5° Fahr.

Quantity of water.	Specific gravity.
00 per cent.	0·8070
10 "	0·8371
20 "	0·8649
30 "	0·8873
40 "	0·9072
50 "	0·9232
60 "	0·9429
70 "	0·9576
80 "	0·9709
90 "	0·9751
95 "	0·9857

The same authority says, if the above results are brought to a temperature of 60° Fahr., it will be found there is an almost complete correspondence between alcohol and wood spirit, and that the latter, equally with the former, exhibits a maximum of contraction, which always occurs on the combination of one part of wood spirit with three parts of water, *id est*, in a mixture containing 45·75 per cent. of water. **URE** has also constructed a table of the specific gravities of mixtures of wood spirit and water; but he has given 0·8136 as the specific gravity of anhydrous wood spirit, at a temperature of 60° Fahr. The lowest specific gravity to which pyroxylic spirit has been brought in this country, is 0·812. **DUMAS**, however, states that its density at the temperature of 68° is 0·798, and that of its vapor 1·120, and that its point of ebullition is 152°, at a pressure of thirty inches. **MITSCHERLICH** gives 0·798 as its specific gravity, and 180° Fahr. as the boiling point. **SCANLAN** gives 0·828 as the specific gravity, and 150° as the boiling point. The specific gravity 0·798, appears to be the correct one, as found by **DUMAS** and **MITSCHERLICH**, and from several experiments the Editor performed in Germany, its boiling point ranges between 150° and 160° Fahr.

Acetone, anesite, eupion, *et cetera*, in variable proportion in wood naphtha, cause the density to alter considerably; likewise its solvent power, as regards shell-lac, sandarac, and other resins, is materially affected by the presence or absence of such bodies. Their existence is to be attributed to the various methods of preparing the spirit, also to the want of proper care in managing the operations to which it is subjected. Pure pyroxylic spirit will not answer every purpose for which it is required in the arts. The purest, and that possessing the lowest specific gravity, is preferable for lamps as a source of heat; but for dissolving resins, and especially gum sandarac and mastic, painters and French polishers choose spirit holding some of the impurities in solution. Wood spirit of a low specific gravity, and devoid of acetone, *et cetera*, is procured by liming the raw liquor and distilling, whilst that obtained by distilling off the refined portion of the crude liquor, without saturating with the caustic earth, is an excellent menstruum for the solution of certain resins. The spirit in the former case has an incipient gravity, and is miscible with water, while in the latter it is weaker, and water renders it milky.

Pure pyroxylic spirit is sometimes used medicinally in pulmonary affections. It is readily distinguished from pyroacetic spirit by a concentrated solution of chloride of calcium, which is miscible with the wood spirit, and not with the pyroacetic spirit or acetone.

PURIFICATION OF PYROLIGNEOUS ACID, OR WOOD VINEGAR.—The purification of the acid is effected by saturating the crude liquor remaining after the spirit has been separated, with a base, evaporating to dryness and calcining the dry salt, so as to decompose the oleaginous and tarry matters present, and afterwards distilling this body with an acid—sulphuric or hydrochloric acid—and rectifying the distillate repeatedly over chloride of calcium or carbonate of soda. Lime or soda is generally employed for this purpose. The acid liquor is run off from the still into the tanks, after the naphtha has been expelled, to deposit a portion of its impurities; it is next pumped into another pan, and milk of lime, or burned lime, made into a thick paste with water, added slightly in excess, and the mixture boiled for a short time, and then run off into a vessel to rest for ten or twelve hours. During this time the excess of lime and part of the impurities combined with it precipitate, when the supernatant liquid is ready to be pumped into the evaporating pans. If the crude acid liquor is distilled before neutralizing with lime, the distillate is saturated with lime in an appropriate cistern or vat, and when the solid matters have subsided, the clear fluid is pumped into the evaporating pans. In some works the evaporators are wooden vessels, lined with lead, in which is a coil of iron piping, through which steam passes, while in others they use shallow pans of sheet-iron, having a fire beneath them. In either case the liquid is frequently stirred with a large wooden spatula, and the matters which rise to the top during evaporation are carefully skimmed off.

As the evaporation of the liquor advances, the acetate of lime crystallizes, forming a layer on the surface; this is collected with large scoops or ladles, and deposited in baskets, supported on a frame, which are directly over the pans, and thus the cooling of the drainings is prevented. The whole of the acetate of lime is thus removed, and if the crude acid be distilled previous to saturation with lime, the acetate of lime which it produces is called *grey acetate,*—if the acid be neutralized without distillation, the lime salt is called *brown acetate.* The acetate is then heated in a drying furnace at a temperature of 450° Fahr., to carbonize the resinous and other impurities. To obtain the pure acid, the grey acetate of lime is dissolved in water till the solution has a specific gravity of 1·200; filtered to separate the carbon which results from the decomposition of the tar, *et cetera;* sulphate of soda, in powder, is added, and the whole menstruum briskly agitated, to insure the complete decomposition of the lime salt. Sulphate of soda is to be added until a small portion of the liquor shows no precipitate on the addition of a concentrated solution of this salt. The quantity of crystallized sulphate of soda required to effect a complete decomposition, is about four times the weight of acetate of lime operated upon; this large amount of the decomposing body needed, is owing to the formation of a double salt, as expressed below.

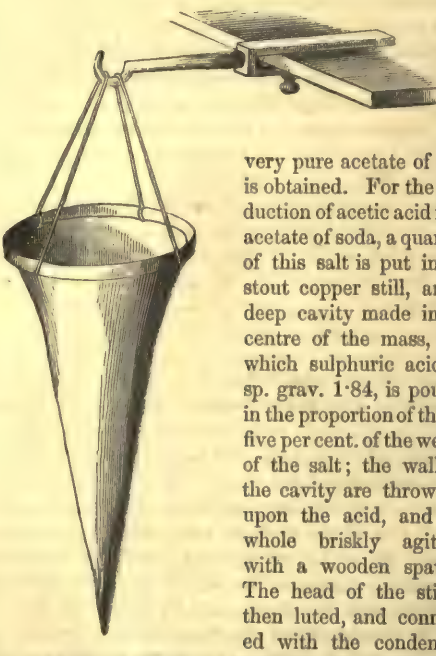
$$\underbrace{\mathrm{Ca\,O,\ C_4\,H_3\,O_3}}_{\text{Acetate of lime.}} + 2\,(\mathrm{Na\,O,\ S\,O_3}) = \underbrace{\mathrm{Na\,O,\ C_4\,H_3\,O_3}}_{\text{Acetate of soda.}}$$

$$+ \underbrace{\mathrm{Ca\,O,\ S\,O_3,\ Na\,O,\ S\,O_3}}_{\text{Double salt.}}.$$

The solution of acetate of soda, after the subsidence of the sulphate of soda and lime, is drawn off to evaporate, and the precipitate washed with water till the liquor is nearly tasteless; the washings may be retained to dissolve fresh quantities of acetate of lime. The acetate of soda liquor is concentrated in pots six feet diameter, and three feet deep, taking care to separate any impurities that may rise to the top, till it acquires a density of 1·300. If it happened that an excess of sulphate of soda had been used in the decomposition of the lime salt, it will now crystallize; it is removed by the scoops or ladles, and thrown into a wicker basket above the evaporating pans, so that the drainings may flow back to the remaining liquor without cooling. After separating the crystallized sulphate of soda, the liquor is allowed to rest for eight or ten hours, to deposit impurities—tar, *et cetera*—that are liberated during the boiling, and afterwards drawn off to the crystallizing pans, where it remains for three to five days. The crystals are then removed, and the mother liquor again concentrated to 1·300, the tarry matters removed as before, and run off to recrystallize; and so on, till the mother liquor no longer yields crystals. This liquor is evaporated to dryness, and the residue calcined; at a red heat, carbonate of soda is formed, and may be extracted by solution in water, or the brownish residue is calcined at 450° Fahr., and acetate of soda dissolved out by water. The crystals of soda salt above obtained are dissolved in fresh quantities of water, and re-evaporated till the solution is 1·500; left to repose for ten hours, the resinous bodies separated, and recrystallized at a density of 1·50: the mother liquor is treated as above detailed.

Next, the crystals are allowed to undergo the aqueous fusion at a temperature of 400°, in an iron pot, and the mass kept constantly stirred till the whole of their water of crystallization is eliminated. During this part of the operation, the greatest precautions are to be observed as to the maintaining of an even temperature—450° Fahr.—and guarding against any sparks coming into contact with the torrefying mass; this would destroy the whole of the compound, as it burns like tinder in contact with fire. A white fume rising from the liquefied salt is an indication that a part is suffering decomposition from the too elevated temperature, which should be immediately checked by throwing open the fire doors, or removing the fire altogether, if the pot be too hot. The termination of the drying is known by the subsidence of frothing, and by the fused mass presenting the appearance of an oily liquid, at which stage it is drawn off by a pipe issuing from the bottom of the pot, or it may be ladled out, allowed to cool on iron plates, and, when solidified, broken up into fragments. On dissolving this compound in twice its weight of water, filtering through bags similar to Fig. 25, and crystallizing, a very pure acetate of soda is obtained. For the production of acetic acid from acetate of soda, a quantity of this salt is put into a stout copper still, and a deep cavity made in the centre of the mass, into which sulphuric acid, of sp. grav. 1·84, is poured, in the proportion of thirty-five per cent. of the weight of the salt; the walls of the cavity are thrown in upon the acid, and the whole briskly agitated with a wooden spatula. The head of the still is then luted, and connected with the condensing worm, and the distillation carried on at a very gentle heat. The worm should be of silver or porcelain, as also the still head, and even silver solder should be used to connect the joinings in the body of the still.

Fig. 25.



In some factories it is usual to have the lower half of the still encased in an iron jacket, which receives high pressure steam, or holds oil, tallow, or fusible metal: when steam is used, the under part of the iron jacket should be furnished with a stopcock, which is turned on at intervals, to allow the condensed water to flow off; and where oil or tallow is the medium that gives heat to the boiler, a safety tube should rise, by which any oleaginous vapors are carried off if the temperature should happen to be too high. The iron jacket is placed directly over the fire in case of the oils or fusible metal being employed, and the heat given off by those substances is sufficient to distil the acid. Towards the end of the distillation, the acid passing over acquires an empyreumatic odor: as soon as this is observed the receiver must be changed, and the last portions collected in a separate vessel. An almost colorless acid, of spec. grav. 1·05, containing about forty-five per cent. of anhydrous acetic acid, passes over. The slight coloration of the acid, or any empyreuma, may be almost immediately removed by infusing with it a very small quantity of well-burnt, well-washed bone-black; or by running it off into barrels which are replenished with chips of beechwood; it will be found, in about a fortnight, to be clarified and ready for sale. Strong acid is procured by distilling the preceding acid, of spec. grav. 1·05, with fused chloride of calcium, receiving the distillate in a refrigerator; part of the acid which passes over crystallizes; the crystals are removed and dissolved in their own water, and subjected to a second rectification, as before, and this continued till the whole of the acid crystallizes at 55° Fahr.: these crystals deliquesce at the ordinary temperature, giving the acid of spec. grav. 1·063, which is a monohydrate. If the acid, spec. grav. 1·05, be required for culinary purposes, pickling, *et cetera*, it is diluted with about five times its weight of water, to render it of the same strength as revenue proof vinegar; a little caramel—burned sugar—dissolved in water, and occasionally a little acetic ether, are added, to confer a deep color, and aroma.

When the acid is required for the fabrication of the other compounds used in the arts and manufactures, where great purity is not essential, it is prepared direct from the crude lime salt by distillation with sulphuric acid. In some of the Welsh factories, the following is the mode of working:—A cast-iron cylinder, four feet long and two feet in diameter, having one end closed tightly by a stout iron door, the front end being secured by a door firmly screwed on, which may be removed at pleasure, is provided; this door is divided into two parts, the upper part being two-thirds, and the lower, one-third of the whole. In the upper division a stout iron rod passes, and runs along the length of the cylinder to the opposite end, where it is fixed in a groove. From that portion of the rod which is within the cylinder, numerous bars project at right angles, and extend through the whole concavity of the cylinder. A movable door occupies the lower division of the front of the apparatus, through which the contents of the interior are withdrawn, and the convex part of the cylinder is furnished with an opening, to which a door is screwed: the apparatus, thus completed, is termed an *agitater*. The cylinder is placed horizontally in brickwork, and the opening in the upper part affords the means by which the proper quantity of acetate of lime and sulphuric acid is introduced, in the proportion of 100 of the former to 60 of the latter. After charging the cylinder, motion is communicated to the axis passing through the upper part of the door, either by machinery or manual labor. When the contents of the agitator are completely comminuted, it is then drawn off by means of the movable door in the lower part of the front end, into a vessel placed below to receive it, out of which the half-liquid or pulpy mass is ladled into strong cast-iron trays, of three to four feet in length, two feet wide, and about two inches in depth: these trays are afterwards deposited in an oven five feet long, three wide, and the same in height, being separated from one another by iron rods laid between them, and on which they rest. A pipe passes off from the far end of this case, wherein the gaseous acetic acid flows to the condenser, which is generally a stout leaden pipe, placed in a stream of cold water. Fire is directly applied to the bottom of the oven, and continued till the whole of the acid is expelled. The crude acid that is thus procured in large quantities, is, for the most part, forwarded to London for purification from foreign bodies, such as sulphurous acid, sulphur, and traces of sulphide of hydrogen, arising from the action of the carbonaceous matters in the salt upon the sulphuric acid; resinous and tarry bodies, with a large quantity of coloring matters, also accompany the acid, and from which it is freed by redistilling with a little bichromate of potassa, or bicarbonate of soda. This second distillation is effected in leaden vessels, which are encased by a cast-iron cylinder.

The ordinary yield of acetic acid from one ton of the crude acetate of lime, when treated with twelve hundredweight of rectified sulphuric acid, spec. grav. 1·84, or fifteen hundredweight of acid of 1·77, and one ton of water, is one ton and a half of rough acid, of spec. grav. 1·05. Copper stills, or cast-iron stills with flat earthenware or tin heads, often serve for the second distillation.

To obtain acetate of lime in a sufficient state of purity, VÖLCKEL saturates the crude acid with lime, without previous distillation, whereupon a part of the resinous impurities separates in combination with lime, while the rest remains in the liquid, imparting to it a dark-brown color; the liquid is clarified by filtration, or by simply leaving the impurities to settle down, and afterwards evaporated in an iron pot to about one half its bulk. Hydrochloric acid is then added, which causes the dissolved resin to separate, and also the decomposition of the lime-compounds of creasote and other volatile substances; the former collects together in the boiling liquor, so that it can be easily skimmed, and the latter are expelled during the evaporation. The quantity of hydrochloric acid required for this purpose, varies, of course, with the constitution of the wood vinegar, which again varies with the degree of moisture of the wood from which the acid is obtained; but the weight is from four to six pounds for a hundred and fifty litres—thirty-three gallons—of the wood vinegar, or as much as will communicate a slightly acid reaction to the liquor. The solution of acetate of lime is then further evaporated, and ultimately dried at a high temperature, to expel all volatile substances. Evaporation and drying may generally be performed in the same iron vessel; but in operating on a very large scale, it is best to dry the salt on cast-iron plates: the exsiccation requires the greatest care. The volatile empyreumatic substances adhere very tenaciously to the acetate of lime, and to the resin contained in it, and unless driven off by heat they pass over in the subsequent distillation, together with the acetic acid, and impart to it a bad smell; the desiccation must, therefore, be continued till the acetate of lime becomes inodorous, or nearly so: when thoroughly dried, it has a dirty-brown color.

To procure the acetic acid, the purified lime-compound is distilled with hydrochloric acid. The distillation may be performed in a still, with copper head and leaden condensing tube. If the operation be conducted with proper care, neither copper nor lead is found in the distillate. The quantity of hydrochloric acid required cannot be exactly given, because the acetate of lime contains variable proportions of foreign matters, *videlicet*, resin, and chloride of calcium already formed. In general, however, from ninety to ninety-five parts of hydrochloric acid of spec. grav. 1·16, will completely decompose a hundred parts of acetate of lime, without causing the distillate to be much contaminated with hydrochloric acid. In any given case, the quantity of hydrochloric acid required is easily determined by an experiment on a small scale. The apparatus may likewise be so arranged as to allow of the subsequent addition of hydrochloric acid, if the quantity first used be found insufficient. Whether the amount introduced is enough, may be known by testing the distillate with nitrate of silver; so long as mere turbidity is produced, one may be sure that the hydrochloric acid is not in excess.

Distillation of the acetic acid proceeds with ease and regularity. The acetate of lime dissolves in the hydrochloric acid, forming a dark-colored liquid, while a quantity of dark resin separates. As the whole mass is liquid, the heat diffuses through it easily; and as the acetic acid passes over between 212° and 248° Fahr., and the acetate of lime has been already exposed in drying to a higher temperature, the distilled acid is but very slightly contaminated with empyreumatic products, resulting from decomposition of the resin: moreover, the resinous matters, being lighter than the chloride of calcium solution, float on the top, and do not form hard incrustations in the still.

The distilled acetic acid has but a very slight empyreumatic odor, which is also very different from that of crude wood vinegar. It is perfectly colorless, and if the hydrochloric acid has not been added in excess, gives but a slight cloud with nitrate of silver. Any yellow tint that it may exhibit, arises from particles of resin mechanically carried over; for the resin, separated from the acetate of lime by the hydrochloric acid, melts as the temperature rises, and forms a fluid layer on the surface of the chloride of calcium solution, which is very apt to cause spirting; the resin should, therefore, be removed as far as possible before distillation, either by skimming it with a spoon, or by filtration through a linen cloth. The specific gravity of the acetic acid obtained by this process, varies from 1·058 to 1·061, and it contains more than forty per cent. of anhydrous acetic acid. As, however, acetic acid of this degree of concentration is rarely used, and a somewhat weaker acid is more easily separated by distillation from the solution of chloride of calcium, it is better to add a certain quantity of water, either before or towards the end of the distillation. A good proportion is one hundred parts acetate of lime, from ninety to ninety-five of hydrochloric acid, and twenty-five of water; this gives from ninety-five to a hundred parts of acetic acid, of spec. grav. 1·015. In this manner, thirty-three gallons of wood vinegar will yield sixty pounds of acetic acid of the above strength. Acetic acid thus obtained, may be still further purified by mixing it with a small quantity of carbonate of soda, and redistilling.

The acid which passes over is free from hydrochloric acid and perfectly colorless, but still retains a slight empyreumatic odor; but this may be removed by distilling it with two or three per cent. of bichromate of potassa instead of carbonate of soda. Acetic acid purified with bichromate of potassa is, in fact, undistinguishable from that which is obtained from pure acetate of soda by distillation with sulphuric acid, or from pure acetate of lime with hydrochloric acid. It does not exhibit the slightest color when heated with strong sulphuric acid, nor does it reduce the merest trace of silver when boiled with nitrate of silver and ammonia. When saturated with oxide of lead, it yields a white salt, the analysis of which agrees perfectly with that of pure acetate of lead. Peroxide of manganese may also be used for the februation, instead of bichromate of potassa; but the acid thus purified, gives, after a while, a slight turbidity with nitrate of silver. Any empyreumatic odor that it may retain, may be removed by digestion with pure animal charcoal. As the acetic acid can be easily freed from hydrochloric acid, a slight excess of the latter during distillation is not injurious; on the contrary, the presence of a small quantity of hydrochloric acid is very useful for the purification of the acetic acid, with peroxide of manganese or bichromate of potassa.

Rectification of acetic acid with bichromate of potassa, or with the peroxide of manganese, may be very well conducted in a copper still, with leaden condensing tube. The acid thus prepared can only be contaminated with a small quantity of acetate of lead. If, however, access of air be prevented during the distillation, this impurity will be confined to the first and last portions of the distillate; and by collecting these apart, to be used for the preparation of acetate of lead, the most part of the acid may be obtained free from lead. By observing these precautions, the operator may dispense with the use of glass or silver heads and condensing tubes. The entrance of air into the condensing tube may be prevented by closing the end of the tube with a cork, through which is inserted a glass tube, bent in the form ∽.

The preparation of acetic acid by the method just described, may be rendered simpler by subjecting the wood vinegar to a previous distillation, and thereby removing the greater part of the resin before forming the lime salt. But this distillation obviously entails increased expense for labor and fuel, because the same liquid must be twice evaporated; moreover, part of the acetic acid remains with the tar in the retort. On the small scale, the loss thus occasioned is unimportant, but in a large manufactory it would amount to something considerable in the course of a year.

By previous distillation of the wood vinegar, the expense may be avoided by the use of a compound still. The vapor of the wood vinegar, instead of being condensed immediately, is made to pass into a copper receiver, containing the quantity of lime required to saturate the acid, which is thereby completely absorbed. If the copper receiver be surrounded by some substance which is a slow conductor of heat, very little aqueous vapor condenses, so that it may be advantageously used to concentrate a solution of lime, resulting from a previous operation. This process is, however, more complicated, and does not yield more acetic acid than the simpler one first described.

The method here recommended is much cheaper, and yields a much purer product, than the ordinary method of distilling impure acetate of lime with sulphuric acid; further, by the addition of hydrochloric acid during the evaporation of impure acetate, the volatile slightly acid bodies contained in the wood vinegar are removed, according to SCHNEDERMANN, more easily than by the use of a solution of chloride of calcium, or by roasting the impure acetate of lime, either *per se*, or with hydrate of lime. In the latter process, even if it attains the desired end, a considerable loss is incurred from decomposition of the acetate of lime, inasmuch as that substance, from its infusibility, does not admit of any exact regulation of the heat.

Hydrochloric, instead of sulphuric acid, being used in the decomposition of the acetate of lime, has this great advantage, that the presence of resin, coloring matter, *et cetera*, in the acetate of lime, is harmless, providing the salt has been sufficiently heated to drive off these free volatile substances. When, on the contrary, sulphuric acid is used, the acetic acid produced always has a bad odor, is saturated with sulphurous acid, and contaminated by a variety of products arising from the deportment of the resins at an elevated temperature. Besides, the sulphate of lime forms a hard crust at the bottom of the retort, and in distilling on the large scale, the under part of the alembic must be heated red-hot to drive out all the acetic acid. The last portions of acid that pass over are often turbid from sulphur, and the odor of sulphide of hydrogen becomes perceptible, that gas arising from reduction of the sulphate of lime to sulphide of calcium at the bottom of the vessel; from this cause cast-iron retorts soon become corroded.

The low price at which pure acetic acid may be obtained by the method above described, will probably lead to its more extended use in dyeing and calico printing, and it may also be advantageously used in the preparation of acetates, especially of acetate of lead.

PURE ACETIC ACID FROM BRANDY VINEGAR.—VÖLCKEL commends a similar process for the preparation of pure acetic acid from brandy vinegar; the process, however, is simpler, inasmuch as brandy vinegar is much less impure than wood vinegar.

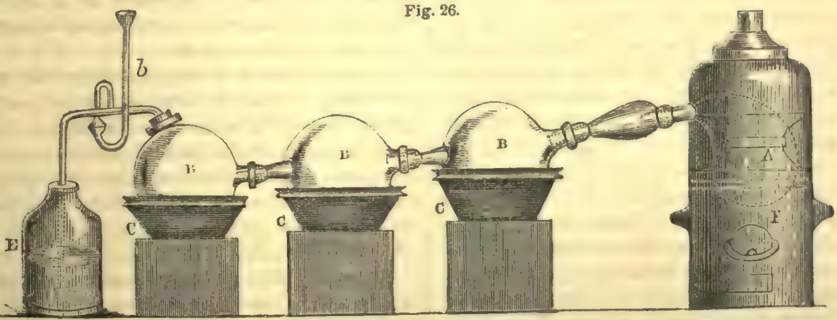
He proceeds:—Strong brandy vinegar—the best for this purpose is that which contains from twelve to fifteen parts of anhydrous acid, a proportion which is obtained in some manufactories—is saturated with lime, and the turbid and colored solution is strained through a linen cloth, and evaporated to dryness in an iron vessel. The dried salt is perfectly white, the coloring matters previously contained in the solution having been, for the most part, destroyed by the action of the air.

The decomposition of the acetate of lime is effected by hydrochloric acid, in the manner already described, excepting that the acetate of lime being less feculent than that obtained from wood vinegar, a larger proportion of hydrochloric acid is required for its decomposition, *videlicet*, about one hundred and thirty parts of acid to one hundred parts of the lime salt.

Final purification of the acid may be accomplished by either of the preceding methods.

AROMATIC VINEGAR.—Crystallized acetate of copper is the salt most usually employed for the preparation of this compound. Twenty pounds of the powdered acetate of copper are introduced into an earthen retort of about two gallons capacity; the retort is luted and carefully dried before applying heat for distilling off the acid, and by this precaution it lasts much longer. The elongated neck of the retort is connected with a tubulated receiver, this is joined to several others, of which the last is furnished with a curved safety-tube, dipped into a vessel of water. The retort is inserted into a furnace, and a gentle heat applied at first, which is afterwards gradually increased; the rapid or slow development of vapor serves as a guide to direct the proper application of the heat. Fig. 26 shows the apparatus on a small scale; F is the furnace which heats the retort, A; B B B are tubulated receivers, immersed in cold water in the coolers, C C C; the last receiver, B, has a WELTER's safety tube, *b*, the long arm of which dips into the water in E, where any uncondensed vapors from the receivers are absorbed. The fire in F is lighted, and the heat gradually raised as long as any vapors pass over; if, on increasing the heat towards the end, no more vapors are given off, the distillation is terminated, the fire is withdrawn, and the apparatus allowed to cool. Twenty pounds of the copper salt produce, by distillation, about ten pounds of rough acid, of a greenish color, and 1·061 spec. grav.; the residuum in the retort consists of six and a half pounds of copper in a metallic state, mixed with a small quantity of charcoal. The crude acid is then rectified in a glass retort

Fig. 26.



of the capacity of about one gallon and a half, to which is adapted a tubulated receiver, and heat applied by means of a sand-bath. A weak acid comes over first, which is collected separately until it acquires a density of 1·072; the receiver is then changed, and the distillation continued till the condensed products begin to acquire an empyreuma, when a third receiver is supplied to collect the last portions. An acid, of spec. grav. 1·080 to 1·088, is found in the second vessel; the first and last portions are redistilled, and mixed with the stronger acid in the second receiver. The acid from twenty pounds of acetate of copper, upon a second rectification, yields six pounds of acid, spec. grav. 1·085; three pounds, spec. grav. 1·042; and half a pound of acid, spec. grav. 1·023. Other metallic acetates may be used instead of the copper salt, but with variable results as to the amount of acid which they yield. Acetates which have easily reducible oxides, as those of copper, silver, mercury, lead, *et cetera*, afford a larger proportion of acetic acid; acetone, carbonic oxide, carbonic acid, and carbide of hydrogen, are likewise evolved in greater or less proportions, and reduced metal is invariably left in the retort. The acetate of silver gives no acetone when submitted to destructive distillation. Acetates, the bases of which retain carbonic acid at a red heat, produce chiefly the carbonate of the base and acetome, but very little acetic acid: such are the acetates of potassa, soda, and baryta; and when the oxide cannot retain carbonic acid at a red heat, as is the case with the acetates of magnesia, zinc, and manganese, the acetone is accompanied by carbonic acid, and the oxides of such metals remain in the retort.

The small amount of acetone which passes over with the acetic acid, in the distillation of acetate of copper, imparts an agreeable aroma; and by the addition of a little camphor or essential oils, the *aromatic vinegar* of commerce is produced.

EXCISE DUTY ON VINEGAR.—The proof vinegar of the revenue has a spec. grav. of 1·0085, and contains about five per cent. of acetic acid. In commerce, this vinegar is represented by No. 24, from the fact that twenty-four grains of pure dry carbonate of soda are required to neutralize a fluid ounce. Weaker vinegars are represented by the Nos. 18, 20, 22, according to their strength; and, as in the foregoing instance, these figures equal the number of grains of carbonate of soda that will saturate a fluid ounce. Formerly, a duty of twopence was paid on every gallon of vinegar imported of the strength above mentioned, and if the vinegar had been double proof, a duty of fourpence was exacted. Now, however, this duty is repealed as regards the home-made vinegar, but a license of five guineas is paid by every manufacturer. The foreign vinegar imported is still subject to a duty of threepence per gallon of the revenue strength.

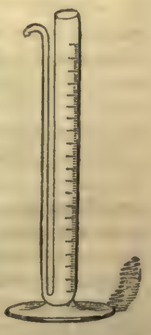
In the United Kingdom, in the year 1848, there were about fifty vinegar factories; five of these were in London, which made nearly half the whole quantity produced.

The specific gravity of vinegar is sometimes ascertained by a species of hydrometer, termed an *acetometer*. By dipping it into the vinegar under examination, and observing the depth to which it sinks, the number of the scale marking the level of the liquid indicates the density of the solution, from which, by means of a table, the per centage of real acid is ascertained.

Vinegar made from dilute alcohol, or ripe wines, in which no great excess of albuminous and other matters is present, can, to a certain limit, be tested with sufficient accuracy by the acetomer; but other vinegar, made from malt, poor wines, and such liquids as contain an excess of organic matters, do not admit of being tested with the required degree of accuracy by this method, since the foreign matters increase the density of the liquid without adding to its quantity of real acetic acid. As was shown at page 3, the specific gravity test is not to be relied on beyond a certain extent, even when an acid is produced from pure alcohol. In some cases the vinegar is saturated with chalk or milk of lime, the solution filtered, and the specific gravity of the acetate of lime liquor ascertained, by which a nearer approximation is arrived at than by the direct testing of the vinegar; yet on neither of these two methods can implicit reliance be placed. BRANDE recommends the following:—A clean dry piece of marble is weighed, and suspended by a silk thread in a known quantity of the vinegar under examination, the solution being occasionally stirred with a glass rod, without detaching any splinters from the weighed marble, till the whole of the acid is saturated, and no further action on the marble is observed. The marble is then taken out, washed with distilled water, dried, and weighed—the loss, in weight, which it has sustained, is equal to the quantity of acetic acid present, the atomic weight of carbonate of lime and dry acetic acid being nearly equal, or as 50 to 51.

The best method of ascertaining the per centage of acetic acid in vinegar, is to neutralize it with pure carbonate of potassa or soda, noting the quantity of these salts required to saturate the acid, and by finding this, the amount of real acid in a sample is ascertained by a simple calculation; for every fifty-three grains of the pure carbonate of soda, or sixty-nine grains of the carbonate of potassa—one equivalent—indicate fifty-one grains, or one equivalent, of anhydrous acetic acid. The examination is made in the following manner:—Five hundred and thirty grains of pure dry carbonate of soda are dissolved in ten thousand grains of distilled water—ten alkalimetrical measures—and this test solution kept in a stoppered bottle for use. An ounce of the vinegar is either weighed or measured, and put into a beaker or porcelain dish, and one thousand grains of the test solution—one alkalimetrical measure, equal one hundred divisions of the alkalimeter, Fig. 27—are taken and poured, in successive small portions, into the vinegar, agitating the solution well with a glass or porcelain rod after each addition. The solution is tested at intervals with blue litmus-paper, and while its color is reddened when dropped into the liquid, and the effervescing continues,

Fig. 27.



free acid is still in the menstruum, and a few drops more of test solution must be added. When the saturation of the vinegar is nearly terminated, heat is applied to expel the carbonic acid, which is absorbed, and would, if not driven off, communicate a faint rose tint to the test paper, and thus cause an error in the results. If the paper still becomes red after heating, a few drops more of the alkaline liquor are poured in, till the paper is only feebly reddened.

Sometimes a few drops of tincture of litmus are added in the beginning, and when the operation draws to a close the litmus regains in part its blue color. This, however, offers no advantage, for the acid may be completely saturated long before the color of the blue litmus makes its appearance. The number of divisions of the test liquor required to saturate the acid is read off, and by a *rule of three* calculation the amount of acid in the sample is found—for example, since five hundred and thirty grains of the alkaline carbonate, equal to ten equivalents, are contained in ten thousand grains of distilled water, one thousand grains of this solution —a hundred divisions of the alkalimeter—contain fifty-three grains, or one equivalent, of carbonate of soda, which are capable of neutralizing fifty-one grains of dry acetic acid. Now, if fifty divisions of the soda solution be added to saturate the ounce of vinegar, we find the amount of acid by the annexed proportion:—

As 100 : 51 :: 50 : 25·5,

which is the quantity of acid present in the fluid ounce of vinegar operated upon. An ounce measure contains four hundred and thirty-seven grains, which, by the above calculation, give twenty-five and a half grains of dry acetic acid, and from this the per centage of acid is estimated:—

As 437 : 25·5 :: 100 : 5·83,

the real amount of acetic acid in a hundred parts of the vinegar examined. The trouble of this calculation is dispensed with by taking five hundred grains of the vinegar, instead of a fluid ounce, and adding to it the test solution as before, observing the same precautions till the acid is neutralized. A hundred divisions of the alkalimeter equal fifty-one grains of dry acetic acid; consequently, every division of the solution will neutralize 0·51 of a grain of dry acetic acid, and by multiplying the number of measures added by the factor 0·51, and dividing the product by 5, the amount is thereby obtained. Thus, if sixty measures are taken, the calculation is—

$$60 \times 0{\cdot}51 = 30{\cdot}60 \div 5 = 6{\cdot}12,$$

the per centage of acid in the vinegar.

Instead of a soda test liquor, a solution of ammonia is used to saturate the acid. This solution is prepared by adding water to concentrated ammonia till the spec. grav. is 0·992. One thousand grains of this dilute ammonia contain seventeen grains—one equivalent—of pure ammonia, which is capable of saturating fifty-one grains —one equivalent—of acetic acid The application of this test is similar to that already described. Five hundred grains of vinegar are weighed out, and the burette filled up to zero with the ammoniacal solution, which is added to the vinegar till neutralized; the calculation is the same as the preceding, that is, multiplying the number of divisions by 0·51, and dividing by 5. There is some difficulty in preserving the dilute ammonia of the same strength, which is an objection to its use; but a uniformity of concentration is insured by introducing into the bottle two glass drops, so adjusted that one remains at the bottom and the other floats just under the surface of the liquid, as long as the test liquor maintains the proper strength. If, by exposure, a part of the ammonia escapes, the specific gravity of the liquor will become proportionably greater, and the glass drops rise—the lower one higher from the bottom, and the upper one partly above the surface. When this happens, more strong ammonia is added, till the hydrostatic drops are properly readjusted.

In each of the preceding modes of testing, it is evident that, should the vinegar contain any admixture of other acids—such as sulphuric acid, hydrochloric acid, or the like—these will increase the quantity of the alkaline solution required to neutralize the weight of vinegar taken for the test; and the amount of acetic acid that results from the preceding calculation is too high in proportion to the quantity of those foreign acids. Preliminary examinations should be made to ascertain if these impurities be present, and, if so, their amount determined.

SULPHURIC ACID IN VINEGAR.—After the conversion of malt, beer, weak wines, *et cetera*, into vinegar, a putrid fermentation often takes place, which decomposes the whole of their acetic acid. It was generally considered necessary that a portion of sulphuric acid should be added, to counteract this tendency of the liquid to decomposition, and to preserve it from turbidity. This addition was permitted to the extent of one gallon of sulphuric acid to one thousand gallons of vinegar, by an Excise regulation, and had, therefore, a legal sanction; but sulphuric acid is now known to be unnecessary in properly prepared vinegars, although still added by some manufacturers for the purpose of increasing the strength of their vinegars, or, in some instances, merely from habit and the indisposition to disturb the routine of an old-established practice. Sulphuric acid in vinegar should be looked upon as a mark of inferior quality; for it is only where the mode of manufacture is defective, that the addition appears to be at all necessary. The seemingly small admixture of one part of sulphuric acid in a thousand of vinegar, cannot be viewed directly as a source of internal injury to the consumer; nevertheless, it does not in the least favor digestion, and it is known that, in larger quantities, it affects the coats of the stomach. Besides the addition of the one-thousandth part of sulphuric acid, many persons—makers or venders—add a far greater proportion, in order to confer that acidity which ought only to be produced by the acetic acid. Some of these admixtures are most dangerous to the community, as often the commonest oil of vitriol is used as the adulterant. The Editor had, not long since, an opportunity of examining a sample of vinegar, and found it contained arsenic, a fact which he attributes to the use of common pyrites vitriol.

Several methods have been given in chemical books for the detection of sulphuric acid in vinegar or acetic acid, some of which cannot be applied unless the sulphuric acid be present in such proportion as would make the most reckless shrink from sending the fabrication into the market. Here will be enumerated a few of the more trustworthy for the qualitative and quantitative estimation of sulphuric acid in vinegars. It should, however, be borne in mind, that vinegar made from wine, malt, *et cetera*, contains some soluble neutral sulphates, these being natural constituents of the grain or grapes from which the wine or fermented wort is obtained; and that, by the more delicate tests, this quantity of sulphuric acid in combination will be indicated.

The most fastidious against adulterations cannot object to the presence of these minute portions of soluble sulphates, since the small amount of acid in the salts is chemically united with a base, and therefore cannot injuriously affect the animal organism. If the vinegar be suspected to contain a greater quantity of sulphuric acid than authorized, it may be ascertained pretty accurately by making a solution of sugar in thirty parts of water, bringing the liquid to a temperature of 190° or 200° Fahr., by means of steam heat; if a drop of the suspected vinegar be added, it will carbonize the sugar, causing a blackish spot to appear at the point where the vinegar came in contact with the saccharine solution. This happens when the vinegar contains the one three-hundredth of its weight of the adulterant; and when the amount ranges between the one six-hundredth and one eight-hundredth of the impurity, a greenish spot appears.

The next and principal test is the precipitation of the sulphuric acid by means of a soluble salt of baryta, in the form of insoluble sulphate of baryta, which falls down as a heavy white powder. Judging from the bulk of the precipitate obtained from a certain quantity of the vinegar, a tolerable inference may be drawn as to the fact of the vinegar containing more than the ordinary amount of sulphuric acid. When only about the eight-hundredth or one-thousandth of the adulterant is present, an immediate white precipitate indicates the presence of sulphuric acid; but this precipitate does not so quickly subside as when larger quantities are present.

For the quantitative determination of sulphuric acid, the best way to proceed is the following:—Half a pound of the vinegar is weighed and evaporated in a porcelain or platinum basin, on a water-bath or by steam heat, till the eight ounces are reduced to one ounce; the basin is then removed from the heat and allowed to cool, and five or six times its bulk of strong spirit of wine or alcohol added, in which the earthy and alkaline sulphates naturally present in the vinegar are insoluble, and consequently fall down. After the precipitate has subsided, the solution is filtered off, and the residue edulcorated twice with dilute spirit. The most part of the alcohol is expelled by evaporation in the water-bath, and the remaining liquid diluted with ten or twelve times the volume of water, and afterwards a solution of chloride of barium poured in as long as a precipitate is formed. The precipitate, after subsidence and filtration of the supernatant liquid, is digested with moderately dilute warm hydrochloric acid, then thrown upon a filter, washed with boiling water till a portion of the washings gives no white precipitate upon addition of sulphuric acid, dried in a water or air bath, and, when dry, burned in a platinum crucible. When accurate results are desired, the precipitate should be detached as much as possible from the filter-paper, and the latter burned in the crucible until the whole of the carbonaceous matter of the paper is destroyed, and the precipitate then introduced, heated to redness, and weighed. Every hundred and sixteen and a half parts of this precipitate indicate forty-nine parts of monohydrated sulphuric acid.

When great accuracy is not required, a solution of chloride of barium is made, of standard strength, by dissolving one hundred and twenty-two grains of the crystallized salt in two thousand grains of distilled water; five hundred grains of vinegar, diluted with twice its weight of water, are poured into a tall and not very wide beaker glass, or precipitating jar; one hundred alkalimetrical divisions are taken and poured gradually from the burette, in small portions at a time, into the vinegar, stirring well after each addition with a glass rod, and then leaving the whole to rest in a warm situation till the precipitate collects at the bottom, after which another addition of the test solution is made, observing the same rule as above given, as long as any precipitate forms. When the last drop causes no precipitate, or, at least, only a very slight one, the number of measures of test solution added are read off, and from this the amount of sulphuric acid is calculated. Since the one hundred and twenty-two grains of the salt—one equivalent—correspond with forty-nine grains of rectified sulphuric acid. and that this quantity is contained in the two thousand grains of liquid, half this solution will contain sixty-one grains of the baryta salt, which quantity equals twenty-four and a half grains of monohydrated sulphuric acid. If fifty measures of the test solution be added to the five hundred grains of vinegar, the per centage of acid is found by multiplying the number of measures, or fifty, by twenty-four and a half, and dividing this product by five hundred; thus—

$$50 \times 24{\cdot}5 = 1225{\cdot}0 \div 500 = 2{\cdot}45 \text{ per cent.};$$

from which 0·1 per cent. should be deducted for the addition allowed by government. Some waters contain a large quantity of sulphates, by which a greater amount of the test solution is required to throw down the entire sulphuric acid, free and combined; but if it be suspected that this is the case, the examination of the water employed should precede the testing of the vinegar, or the analysis should be conducted as indicated in the foregoing, namely, evaporation of the vinegar, and treatment with alcohol, *et cetera*.

HYDROCHLORIC ACID IN VINEGAR.—This acid is not so frequently met with in vinegar as sulphuric acid; indeed, the sophisticator rarely has recourse to it. Its presence may be ascertained by distilling a quantity of the vinegar from a glass retort, to which a condenser is attached, and adding a few drops of a solution of nitrate of silver to the distillate. A white precipitate indicates the presence of hydrochloric acid.

To determine, quantitatively, the amount of the acid, eight or sixteen ounces of the vinegar are distilled, as just mentioned, care being taken not to lose any either in its introduction into the retort or otherwise, till the whole of the liquid has passed over into the receiver. A solution of nitrate of silver is poured into the distillate as long as a precipitate occurs. The solution is left at rest till the white curdy precipitate of chloride of silver falls to the bottom, which is filtered off, washed with a little dilute nitric acid first, and afterwards with distilled water; dried at 212° in a water-bath, ignited in a porcelain crucible, and weighed. From the weight of the chloride of silver, that of the hydrochloric acid is calculated.

A hundred and forty-three and a half parts of chloride of silver are equal to thirty-six and a half parts of dry hydrochloric acid, or one hundred parts of liquid hydrochloric acid of spec. grav. 1·180. If the weight of chloride of silver, from the eight ounces, be sixty grains, the per centage is found as follows:—

$$143{\cdot}5 : 36{\cdot}5 :: 60 : 20{\cdot}34,$$

the amount of acid in the eight ounces of liquid taken; and by multiplying these ounces by four hundred and thirty-seven and a half, the number of grains in a fluid ounce, the number of grains weight operated upon are obtained; thus—

$$437{\cdot}5 \times 8 = 35000 : 20{\cdot}34 :: 100 : 0{\cdot}581$$

per cent. of dry hydrochloric acid.

NITRIC ACID IN VINEGAR.—This acid is rarely employed to adulterate vinegar. If it be suspected, the application of the following test will corroborate or remove the suspicion:—About eight ounces are neutralized with carbonate of soda, the liquid evaporated to dryness, and the residue distilled with a few drops of strong sulphuric acid. The distillate is received in an ice-cold receiver, neutralized with potassa, and a solution of starch paste and iodide of potassium added. If a blue compound—iodide of starch—forms, it is an infallible proof of the presence of nitric acid: a simpler test is to boil a portion of the residue from the preceding with hydrochloric acid and copper turnings; if nitric acid be present, red fumes of nitrous acid, possessing a very characteristic odor, are evolved.

TARTARIC ACID IN VINEGAR.—By evaporating a portion of the vinegar in a water bath, if tartaric acid be present, a viscid mass of the consistence of treacle, and highly acid, remains. On adding alcohol to this substance, and agitating for a short time, the tartaric acid is dissolved; the spiritous extract filtered off, mixed with chloride of potassium, and well agitated, yields a crystalline precipitate of bitartrate of potassa—cream of tartar—in the presence of tartaric acid. It must be remarked that wine vinegar naturally contains some tartaric acid in the form of cream of tartar—this compound being one of the solid constituents of the grapes.

METALLIC SALTS IN VINEGAR.—The salts which are formed in vinegar arise from the action of the acid on the metallic vessels employed. Vinegar made by the *quick* process, or in *vinegar fields*, never contains any of these compounds, except the vinegar is afterwards distilled in metallic vessels; the acid at a high temperature, with an excess of air, acts on the metallic substances of the still or condensing worm. As copper, lead, tin, and zinc, are generally the materials used in the construction of the still or worm, these are the only bodies that have to be looked for in the vinegar. A portion of the vinegar is submitted to a stream of sulphide of hydrogen gas; if a black color or precipitate be produced, copper or lead is present. Another portion, ten ounces, of the vinegar is evaporated to dryness in a basin, and the residue heated to redness in a porcelain crucible, and the whitish ash remaining treated with a few drops of nitric acid, heated, and filtered; if, on treating the solution with ammonia, a more or less blue color is given to the liquid, copper is present. Tin gives a yellow coloration with sulphide of hydrogen. The latter has no action upon zinc; but on the addition of ammonia, or sulphide of ammonium, a white precipitate is formed—a small proportion of iron is sufficient to give a greyish or blackish color to the precipitate. The quantity of salts found in vinegar is generally so very small as not to be detected by the tyro unless a large quantity of the vinegar is evaporated, and the residue submitted to a thorough chemical examination.

Should pepper, chillies, *et cetera*, be added to vinegar for the purpose of conferring more pungency, they may be detected by neutralizing the acid with carbonate of soda, and tasting the liquid; if these bodies be present, the solution will still retain the sharpness peculiar to such spices.

Flies—*musca cellaris*—and eels—*vibrio aceti*—are often found in vinegar; they may be destroyed by passing the vinegar through tubes immersed in boiling water.

The average per centage of fixed matter which remains after evaporating the different vinegars to dryness, is as follows:—

Wine Vinegar,	2·05 to 2·10
Beer Vinegar,	5·00 to 6·00
Cider Vinegar,	1·40 to 1·50

Vinegar, as a condiment, serves admirably for promoting digestion. It exerts a solvent action on the albuminous and proteine compounds of the food; hence the reason of its being constantly served with salads, fish, veal, and other substances rich in such matters. Its free use, however, should be avoided.

Acetic acid is also extensively employed to preserve animal and vegetal substances liable to decay or putrefaction. Wood vinegar is preferable to other varieties, on account of the small quantities of essential oils which it contains, and which render its antiseptic properties more active. The creasote of this acid confers a smoky taste on meats. Vinegar is sometimes concentrated by exposing it to cold, and separating the layers of ice; although the greater part of the water is by this treatment removed, yet a large quantity of acetic acid is likewise abstracted, and where the vinegar is very dilute, the process is not at all economical. Another method is, to keep the vinegar heated at a temperature between 212° and 220° Fahr.; for, while water boils at 212°, the hydrated acetic acid boils at 248°, so that at 212° a large proportion of water is driven off and very little acid; every disadvantage is removed when the boiling point of the vinegar is elevated. **Stein** recommends for this purpose the addition of chloride of sodium, in the proportion of thirty pounds for every hundred pounds of vinegar. The acid then distils over without loss, and is obtained much stronger than in the ordinary mode of distillation.

Some cautions may here be given with reference to the vessels in which vinegar is kept, as these often consist of metals. A painted vessel should never be used, the basis of nearly all pigments being white lead, which readily dissolves in acetic acid, forming sugar of lead—acetate of lead; and many paints contain copper and other metallic substances, soluble in acetic acid, all of which may prove poisonous. Copper vessels may be employed with safety, provided the inner surface be kept bright, and the acid be not suffered to remain in them after cooling. Iron is too easily attacked by the acetic acid to be used; and although the salt which is formed in the liquid—the acetate of iron—is not injurious in small quantity, yet it communicates to food a disagreeable styptic taste.

Common earthen vessels, glazed with oxide of lead—litharge, red lead—part of which is frequently uncombined with the body of the ware, should not be employed; for the acid would undoubtedly dissolve that portion of the oxide, and might even attack the well-burned porcelain itself—the more so if the acid be heated in the vessel. Salt-glazed stoneware, good English pottery, porcelain, glazed or enamelled iron, silver, and copper—under the above precautions—may all be employed for boiling acetic acid or its preparations with safety.

Acetic acid is employed to a large extent in the arts, chiefly in calico-printing and dyeing. When required for these uses, it is united to bases, with which it forms acetates, principally used as mordants. It is likewise used in the preparation of varnishes; for dissolving gums and albuminous bodies. Aromatic vinegar is medicinally applied as a stimulant against fainting, and externally as a rubefacient.

Statistics of the Vinegar Manufacture.—The total number of vinegar makers—not including pyroligneous acid—in the United Kingdom, in 1844, was forty-four. The quantity of vinegar made between the fifth of July, 1843, and the fourth of July, 1844, was 2,828,043 gallons, on which a duty of £24,745. 7s. 6d. had been paid. At present there are about fifty manufacturers who make over 3,000,000 gallons annually; of these the five principal ones are in London, and they make nearly half the entire quantity.

The following table exhibits, under the respective years, the number of vinegar factories in the United Kingdom, during the six years ending with 1846:—

1841.	1842.	1843.	1844.	1845.	1846.
58	59	54	44	60	56

which paid, at the rate of five guineas license fee, the undermentioned sums, namely:

1841.	1842.	1843.	1844.	1845.	1846.
£304. 10s.	£309. 15s.	£283. 10s.	£231	£315	£294

The number of gallons produced by the home factories during the period previous to the repeal of the vinegar duty, was, in

	1841.	1842.	1843.
Gallons,	3,102,098	3,175,722	2,993,061
Duty,	£27,143. 7s. 1d.	£27,787. 11s. 3¼d.	£26,189. 5s. 7½d.

	1844.	1845.	1846.
Gallons,	2,828,043	—	—
Duty,	£24,745. 5s. 7d.	—	—

From the year 1844, tne duty on the home-made was repealed, but a levy of fourpence-halfpenny per gallon of proof strength is paid by that which is imported from foreign countries, of which more or less is received every year. The annexed tables show the number of gallons of foreign vinegar imported into Great Britain during the foregoing period, and chargeable with duty:—

Number of gallons chargeable with duty imported in

1841.	1842.	1843.	1844.	1845.	1846.
53,695	41,311	21,784	88,722	95,967	63,821;

and the quantity retained for home consumption, and chargeable with duty, was, in

1841.	1842.	1843.	1844.	1845.	1846.
Gls.	Gls.	Gls.	Gls.	Gls.	Gls.
22,205	18,139	14,143	63,029	74,236	73,079

During the corresponding four months, ending the 4th of May, of

	1844.	1845.	1846.	1847.
	Gls.	Gls.	Gls.	Gls.
There were entered at the port of London chargeable with duty,	6,360	2,378	6,612	2,677
Of which there were retained for home consumption under duty,	3,465	1,563	4,326	1,966

The number of gallons imported during the three years ending the 5th of January, 1852, was

Year.	Quantities imported into the United Kingdom.	Quantities admitted for Home Consumption.	Amount of duty received thereon.
1850	63,929 proof gallons.	52,697 proof gallons.	£927
1851	87,911 "	69,667 "	1,240
1852	109,168 "	69,897 "	1,221

SESQUIACETATE OF ALUMINA.—*Red Liquor.*—This salt is extensively used by calico-printers, as a mordant of a very superior quality. It may be prepared for laboratory purposes by decomposing a solution of sulphate of alumina by acetate of baryta. Sulphate of baryta and acetate of alumina are formed; the former falls down as a heavy white insoluble powder, and the supernatant liquid contains the acetate of alumina. The decomposition which takes place is represented in the following equation:—

$$\underbrace{Al_2\,O_3,\,3\,S\,O_3}_{\text{Sesquisulphate of alumina.}} + 3\,\underbrace{(Ba\,O,\,C_4\,H_3\,O_3)}_{\text{Acetate of baryta.}} = \underbrace{Al_2\,O_3,\,3\,C_4\,H_3\,O_3}_{\text{Sesquiacetate of alumina.}}$$

$$+\,3\,\underbrace{(Ba\,O,\,S\,O_3)}_{\text{Sulphate of baryta.}}.$$

On evaporating the liquor filtered from the sulphate of baryta to dryness on the water-bath, the salt is obtained in the form of a gummy mass, which is very soluble in water and deliquescent, and parts with its acid at a slightly elevated temperature, leaving a subacetate, and at a red heat pure alumina. The dry mass has the following composition:—

	At. weight.		Per centage weight.
1 Eq. of alumina,	52	=	25·366
3 Eqs. of acetic acid,	153	=	74·634
1 Eq. of sesquiacetate of alumina,	205	=	100·000

Formula:—$Al_2O_3, 3C_4H_3O_3$.

Commercial sesquiacetate of alumina—*red liquor*, from its being colored with lichens—is always met with in the liquid state. It is manufactured for the use of calico-printers, by adding to every gallon of acetate of lime liquor, 2⅔ pounds of alum, agitating the mixture briskly, and then leaving it to rest, in order that the sulphate of lime may settle down. The decomposition of the acetate of lime is known by testing a small portion of the filtered liquid in a tube with a concentrated solution of alum; if a precipitate of sulphate of lime falls, more alum must be added, till the acetate of lime is completely decomposed. The liquor is now filtered off, and the solution concentrated by evaporation till it acquires a spec. grav. of 1·087 to 1·100; allowed to repose for some time to deposit any sulphate of lime, and then drawn off for use or for market. The quality of this liquid as a mordant is inferior, on account of the partly imperfect decomposition of the lime salt, and of the presence of a small portion of lime still retained in the red liquor, which impairs very much the beauty and gloss of the color given to the cloth.

A better mordant is made by decomposing alum by acetate of lead. Since the sulphate of lead is insoluble, the decomposition of the alum solution is more perfect than when acted upon by acetate of lime; still, the red liquor is not a true acetate, but a mixture of acetate and subsulphate of alumina with hydrate of alumina and sulphate of potassa, as will be seen from the recipes in general use for its manufacture. Were an equivalent of sulphate of alumina decomposed by corresponding three equivalents of acetate of lead, a sesquiacetate of alumina would result; in practice, however, it is found more advantageous to employ equal parts of alum and sugar of lead, or rather a less quantity of the latter. The alum is dissolved in boiling water, and the powdered acetate of lead added to the solution. About one-tenth of crystallized carbonate of soda, or a little carbonate of lime, is added to the alum, to combine with the free acid. The three following recipes serve to indicate the proportions employed:—

No. 1.—Dissolve 100 lbs. of alum in 50 galls. of boiling water, and add 100 lbs. of acetate of lead in fine powder, stirring the mixture well at first, and likewise several times during the cooling.

The clear supernatant liquid consists of an acetate of alumina, sulphate of potassa, and a little subsulphate of alumina.

No. 2.—Dissolve 100 lbs. of alum in 50 galls. of water; to the solution add slowly 10 lbs. of crystallized carbonate of soda, and then stir in 100 lbs. of acetate of lead in powder.

No. 3.—Dissolve 100 lbs. of alum in 50 galls. of boiling water, and add in small portions 6 lbs. of crystallized carbonate of soda, and then stir in 50 lbs. of acetate of lead in powder, as before.

Nos. 2 and 3 contain acid acetate of alumina, basic sulphate of alumina dissolved in acetic acid, and sulphates of potassa and soda. No. 2 becomes cloudy at 154° Fahr., and gelatinizes at 165°; No. 3 clouds at 176°, and gelatinizes at 192°; the cloudiness disappears on cooling, and is entirely prevented by an excess of alumina in the solutions. According to certain experiments, it appears that the activity of the red liquor is not wholly dependent upon the amount of acetate of alumina which it contains, as a portion of the salt is converted into a basic sulphate which combines with sesquiacetate of alumina; on basing the goods in this solution and drying, a portion of the basic acetate combines with the basic sulphate of alumina; and on subsequently submitting the goods to the drying-bath, acetic acid is partly volatilized, and the aluminous basic compound remains perfectly combined with the cloth.

Further, it is shown that it is immaterial, as to the effect on the texture, and the beauty of color produced on the cloth, whether one hundred pounds of alum be decomposed by one hundred and twenty-five, or seventy-five pounds of acetate of lead, since the acetate of alumina acts by giving up its base to the fibre of the cloth, and that this is effected as well when a basic sulphate of the earth is present as when it is wholly in the form of a sesquiacetate. **Runge** has made some experiments, by which he shows that the quantity of acetate of lead should be always one hundred and twenty pounds to every hundred pounds of alum, and that even the amount of water employed affects the quality of the product. He based equal weights of cotton fabric in each of the following solutions, made by adding—

100 lbs. of alum,
75 lbs. of acetate of lead, and
280 lbs. of water together, agitating the mixture, and filtering:

Secondly, by dissolving—

100 lbs. of alum in
448 lbs. of water, and adding
120 lbs. of acetate of lead in powder, agitating the mixture, and filtering off the clear liquor, as above.

The fabrics being allowed to remain in an equal measure of these solutions for the same time, and dried at the same temperature, were washed with equal quantities of hot water; the washings from the cloth mordanted in the first solution contained much alumina, while only very slight traces were indicated by the washings from the cloth steeped in the second solution. The usual addition of carbonate of soda, to the extent of about one-tenth of the alum employed, acts advantageously in the manufacture of red liquor, where a low proportion of sugar of lead is used, by uniting partly with the sulphuric acid, and producing a basic sulphate, as well as acetate of alumina, as mentioned above.

However, it appears, from practical observations, that a sulphoacetate of alumina is to be preferred, as giving the most satisfactory results. Mr. **Calvert** states, that a mordant of the composition—

$$Al_2O_3\left\{\begin{matrix}SO_3\\2C_4H_3O_3,\end{matrix}\right.$$

is the best adapted for fixing the colors, on account of the excess of alumina in such a solution above those which contain, besides the aluminous salts, salts of the alkalies, which are inert in the uses for which red liquor is manufactured.

The preceding he prepares by mixing together—

453 lbs. of ammonia alum,
379 lbs. of acetate of lead, and
1132 lbs. of water;

or,

383 lbs. of sulphate of alumina,
379 lbs. of acetate of lead, and
1132 lbs. of water;

or,

453 lbs. of alum, and a quantity of solution of acetate of lime, amounting to one hundred and fifty-eight pounds;

or,

333 lbs. of sulphate of alumina, with the same amount of acetate of lime solution.

On agitating the foregoing mixtures, decomposition takes place; sulphate of lead or of lime is thrown down, and a sulphoacetate remains, with an equivalent of sulphate of ammonia from the ammonia alum. Instead of alum, many printers now use sesquisulphate of alumina in the fabrication of this mordant, which is much more economical, as the solution of this salt, brought to the standard strength, or 1·085 spec. grav., contains more alumina than the ordinary red liquor of that strength, as the following analyses show:—

COMPOSITION OF FOUR MORDANTS PER GALLON.

	Formula. $Al_2O_3, SO_3, 2\,C_4H_3O_3 + NH_4O, SO_3$.		Formula. $Al_2O_3, SO_3, C_4H_3O_3 + NH_4O, SO_3$.	Formula. $Al_2O_3, SO_3, 2\,C_4H_3O_3$.
	Mordant A.	Mordant B.	Mordant C.	Mordant D.
	Grs. Oz. Grs.	Grs. Oz. Grs.	Grs. Oz. Grs.	Grs. Oz. Grs.
Alumina,	1680·0 = 3 368	1830·0 = 4 80	1239·0 = 2 365	2164·4 = 4 414
Acetic acid,	3369·8 = 7 307	3570·0 = 8 170	1281·7 = 2 406	3679·2 = 8 179
Sulphuric acid,	2642·5 = 6 17	2800·0 = 6 175	3017·0 = 6 392	1664·6 = 3 352
Ammonia and water,	674·1 = 1 236	910·0 = 2 35	653·1 = 1 215	

ACETATE OF AMMONIA—*Spirit of Mindererus*—in solution, is obtained by saturating distilled vinegar with carbonate of ammonia; this salt constitutes the *liquor ammoniæ acetatis* of the *Pharmacopeia*, which has long been used in medicine as a diaphoretic. When equal weights of chloride of ammonium and acetate of potassa are distilled together, at an incipient temperature ammonia is at first eliminated, and afterwards binacetate of ammonia distils over, in the form of an oily liquid— $\underbrace{2\,(NH_4Cl)}_{\text{Chloride of ammonium.}} + \underbrace{2\,(KO, C_4H_3O_3)}_{\text{Acetate of potassa.}} = \underbrace{NH_4O}_{\text{Ammonia.}} + \underbrace{(NH_4O, 2\,C_4H_3O_3)}_{\text{Binacetate.}}$ —which concretes into acicular crystals, deliquescent, and dissolved in all proportions by water and alcohol. Dry ammonia, transmitted into the fused binacetate, converts it into the solid neutral acetate; a white inodorous salt, easily soluble in water and alcohol, and converted by heat into ammonia and the binacetate of ammonia—

$$\underbrace{NH_4O, C_4H_3O_3, HO, C_4H_3O_3}_{\text{Binacetate of ammonia.}} + \underbrace{NH_4O}_{\text{Ammonia.}} = \underbrace{2\,(NH_4O, C_4H_3O_3)}_{\text{Neutral acetate.}} + HO.$$

Binacetate of ammonia forms striated prisms, fusible at 168°, and subliming unchanged at 248°.

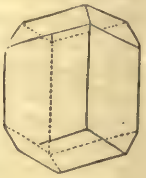
The neutral acetate of ammonia has the composition:—

	Atomic weight.	Centesimally represented.
1 Eq. of acetic acid,	51·00	38·93
1 Eq. of oxide of ammonium,	26·00	19·84
6 Eqs. of water,	54·00	41·23
	131·00	100·00

Formula:—$NH_4O, C_4H_3O_2 + 6$ aq.

ACETATE OF COPPER.—There are several acetates of copper, one of which is of the suboxide, the others being of the protoxide of copper. Of the latter, the most important in the arts are the neutral acetate of copper, the bibasic acetate—*verdigris*—and the tribasic acetate of copper. The neutral acetate of copper is formed by dissolving the hydrated oxide of copper in acetic acid, or by precipitating a solution of sulphate of copper by acetate of lead or baryta, filtering off the precipitated sulphate of lead or baryta, and evaporating the filtered liquid, and crystallizing. The crystals are in oblique rhombic prisms—Fig. 28—of a dark-green color, and possess a disagreeable metallic taste; soluble in about thirteen and a half parts of cold, and five of boiling water. The composition of the neutral acetate is:—

Fig. 28.



	Atomic weight.	Per centage quantity.
1 Eq. of oxide of copper,	40	40·00
1 Eq. of acetic acid,	51	51·00
1 Eq. of water,	9	9·00
	100	100·00

Formula:—$CuO, C_4H_3O_3 + HO$.

Acetate of copper was formerly employed in the manufacture of acetic acid. The suboxide of copper is obtained in red octahedral crystals when the neutral salt is heated with organic substances, such as sugar, honey, starch, *et cetera.*

When the commercial verdigris is dissolved in dilute acetic acid, and the salt crystallized at 40° to 45° Fahr., an acetate with five atoms of water is obtained, in beautiful blue oblique four-sided prisms. On raising the temperature to about 86°, the crystals almost instantaneously lose their blue color, and acquire a greenish hue; four atoms of water are expelled, and neutral acetate remains, with one atom of water.

Its chief use in the arts is in making pigments, and for resisting the blue color which the indigo would communicate in the indigo-bath of the calico-printer.

In the latter case, its mode of action depends on the readiness with which it parts with oxygen, whereby the indigo is oxidized before it can exert any action on the cloth, being itself reduced to the state of acetate of suboxide of copper. Verdigris is occasionally employed as a transparent green water-color or wash for tinting maps.

Bibasic Acetate of Copper.—*Verdigris; Ærugo.*—This salt is formed by exposing thin copper plates, in a confined space, to the combined action of air and moisture, or by submitting copper plates to the action of fermenting *marcs*—refuse from the wine factories; in the course of a few days, a coating of subacetate forms on the plates, which may be scraped off, and the remaining part of the plate submitted to a fresh operation, till all the copper is converted into verdigris.

The manufacture of verdigris on the large scale is conducted as follows:—In France, the chief seats of this manufacture are at Grenoble and Montpellier, where the operations are conducted in a rude but effective way, and usually by women. Husks and refuse of grapes from the wine factories, not entirely exhausted of their juice, are spread loosely in casks until the acetous fermentation takes place. The casks or vessels are covered with matting, to protect them from dirt. The limit to which fermentation of the marcs should be carried, is known by introducing a test sheet of copper into the mass for twenty-four hours; if, on withdrawing it at the end of that time, it is found covered with a uniform green coating, the proper degree of fermentation is reached, otherwise the mass is allowed to remain a day or two longer. Alternate layers of sheets of copper of one twenty-fourth of an inch thick, and the fermented marcs, are introduced into large casks, observing that the top and bottom layers are of the latter.

Sheets of copper are prepared by hammering bars of the metal to the above thickness—the more compact the copper sheets, the better—and they are then cut out into pieces of six or eight inches long by three to four broad. These plates are immersed in a concentrated solution of the verdigris, and dried over a charcoal fire; then heated to about 200° Fahr., being held by a cloth in the hand, and packed in the vessels with layers of the fermented husks, as above-mentioned. If the plates be not immersed in the solution of the acetate before packing in the casks with the fermented stalks and skins of the grape, they are liable to be covered with a black coating, instead of the green acetate. The quantity of metal required to fill each vessel is between thirty and forty pounds. Twenty days are sufficient to complete the corrosion of the copper sheets, and induce their combination with the acetic acid present in the marcs, but often sixteen or twelve days perfect the work. After this period, the upper layer of marcs will appear whitish, and if the whole has worked favorably, the plates will be covered with silky crystals of a green color. The plates are then taken from the casks, and dried in the air for two or three days, after which they are moistened with water and again placed to dry, by laying them upright against each other for a week. This process of moistening with water is continued at regular intervals of a week, for six or eight times. By this mode of operation, the plates swell and become encrusted with increasing coatings of the copper salt, which are detached from the remainder of the plates by a copper knife. The scraped plates are submitted to a fresh treatment, till the whole of the copper is converted into verdigris. After scraping off the salt, it is made into a thick consistent mass by kneading it with a little water, and in this state it is packed into leathern bags, which are placed in the sun to dry, until the mass hardens and forms a tough substance like the commercial article.

At Grenoble the process is nearly the same as above, excepting, that instead of moistening the plates with a solution of subacetate of copper, they employ acetic acid. In Germany, Sweden, and England, the manufacture is somewhat different from the preceding, inasmuch as, instead of the fermented marcs of the grapes, woollen cloths steeped in pyroligneous acid are used, which are placed alternately with the copper plates in a square wooden box. The cloths are moistened with acetic acid every three days for twelve or fifteen days, till small crystals begin to form on the plates. When this happens the cloths are partly withdrawn, and a space allowed for the circulation of the air, the whole being moistened weekly with water. Generally, five or six weeks elapse before the completion of the work.

Acetate of copper is likewise made by acting upon thin sheets of copper, in small vessels, with acetic acid. The copper is not immersed in the acid, but nearly touches its surface; a temperature of about 150° to 180° Fahr. is maintained during the operation. The plates become, in time, coated with acetate, as in the forementioned processes, which is scraped off and dried for the market.

The composition of pure verdigris is:

	Atomic weight.	Containing centesimally.
2 Eqs. of oxide of copper,	80	43·24
1 Eq. of acetic acid,	51	27·57
6 Eqs. of water,	54	29·19
1 Eq. of bibasic acetate of copper,	185	100·00

which, on comparison with the analysis of the best French and English manufacture, tells in favor of the latter.

	Theory.	French Verdigris, centesimally represented.	English Verdigris, centesimally represented.
Oxide of copper,	43·24	43·50	44·25
Acetic acid,	27·54	29·30	29·62
Water,	29·19	25·20	25·51
Impurities,	—	2·00	0·62
	100·00	100·00	100·00

Formula:—$2\,CuO,\ C_4H_3O_3 + 6\,HO$.

This salt is often employed in painting, and likewise in calico-printing, for precisely the same purpose as the neutral acetate; namely, as a resist paste in the indigo dye-bath.

Good verdigris should be dry, have a fine bluish-green color, and be soluble in dilute acetic and sulphuric acids, and also in ammonia.

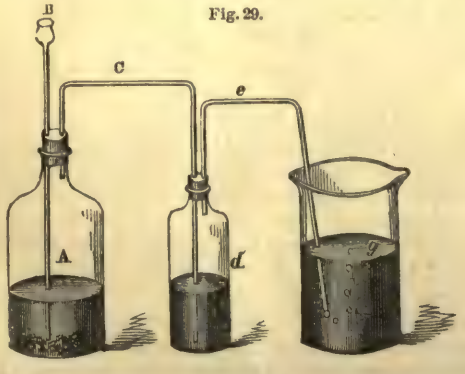
Verdigris is often adulterated, generally with finely ground pumice, chalk, and sulphate of copper. The purchasers acquainted with this article judge of the relative purity of the sample from its bright color, and by kneading it on the palm of the hand with a little water; by the latter test the presence of sand is detected, as the subacetate alone should form a paste free from any grittiness.

For the detection of chalk—carbonate of lime—a weighed portion of the verdigris, in powder, is introduced into a flask, and hydrochloric acid poured upon it; if effervescence takes place, it indicates the presence of carbonates; should, however, no effervescence occur, and, at the same time, a residue of silica remains undissolved, it shows that pumice, or some analogous body, is the adulterant; the residue is greater or less in proportion to the extent of adulteration.

If the hydrochloric acid solution of the above be filtered off, and the residue, being well washed, dried in a water-bath at 212°, and afterwards burned in a weighed platinum crucible till the whole of the charcoal of the paper is consumed, and weighed—the increase of weight will give the amount of insoluble impurities in the sample. On adding chloride of barium to the filtered liquid and washings, a white insoluble precipitate of sulphate of baryta will fall down, if sulphates of copper or iron be present. By placing the beaker on the hot sand-bath the precipitate quickly settles down, after which it is filtered off, washed with boiling-hot water as long as any chloride of barium is extracted, and then placed in the water or air-bath to dry: the precipitate is now to be detached from the filter, upon a sheet of clean dry glazed paper; the filter is burned alone in the platinum crucible till the ashes contain no charcoal from the paper; the precipitate is then introduced, heated to redness, and weighed. One hundred and seventeen grains of the precipitate—corresponding with forty grains, or one equivalent of anhydrous sulphuric acid—equal eighty grains of anhydrous sulphate of copper, or one hundred and twenty-five grains of that salt in crystals.

The amount of the lime compound may be ascertained by weighing out one hundred grains, and dissolving them in a beaker-glass with hydrochloric acid, the clear solution filtered off from the residue, and a current of sulphide of hydrogen gas passed through the liquid, till the whole of the copper is thrown down in the form of a brownish-black precipitate. The sulphide of hydrogen—hydrosulphuric acid—is generated in an apparatus like the annexed—Fig. 29:

Fig. 29.



A is a bottle containing pieces of sulphide of iron, and a few ounces of water; through the cork two tubes pass, the funnelled one, B, reaches to the bottom, and the other, C, opens at a quarter of an inch below the cork, which should fit the bottle air-tight. The sulphide of hydrogen is generated by pouring, through the funnel tube, B, some strong sulphuric acid, which reacts on the sulphide of iron, giving rise to the gas, which passes off by the tube, C, bent at right angles, the longer limb passing through the cork of the bottle, *d*, which contains some distilled water, for the purpose of washing the gas. A second tube, *e*, bent at right angles, conveys the gas to the beaker-glass, *g*, containing the solution, from which the substance is to be precipitated.

The subjoined equation exhibits the decomposition of the sulphide of iron by the sulphuric acid:—

$$\underbrace{\mathrm{Fe\,S}}_{\text{Sulphide of iron.}} + \underbrace{\mathrm{H\,O,\,S\,O_3}}_{\text{Sulphuric acid.}} = \underbrace{\mathrm{Fe\,O,\,S\,O_3}}_{\text{Sulphate of iron.}} + \underbrace{\mathrm{H\,S}}_{\text{Sulphide of hydrogen.}}$$

When the whole of the copper has been precipitated as sulphide, and the menstruum evolves a strong odor of the precipitant, it is filtered off, edulcorated with water, and the washings added to the filtrate. Ammonia, in slight excess, is now poured into the solution, then oxalate of ammonia, and the beaker-glass placed on the sand-bath. When the oxalate of lime has subsided, it is collected, washed with water, dried as the preceding precipitates, and burned in a platinum crucible. The ignition should be gentle, and at a heat little above dull redness, so as not to expel carbonic acid from the carbonate of lime, which is formed by the action of the heat on the oxalate of lime, as is shown in the annexed decomposition:—

$$\underbrace{\mathrm{Ca\,O,\,C_2\,O_3}}_{\text{Oxalate of lime.}} = \underbrace{\mathrm{Ca\,O,\,C\,O_2}}_{\text{Carbonate of lime.}} + \underbrace{\mathrm{C\,O},\text{ expelled.}}_{\text{Carbonic oxide.}}$$

The weight of the carbonate of lime obtained is equal to the amount of that adulterant added to the verdigris. Verdigris generally contains about three per cent. of impurities, and sometimes the insoluble matter in it is six per cent.; in such a case, however, the article is of inferior quality.

Formerly, the manufacture of verdigris was one of the most lucrative in Belgium, and it was also carried on profitably in France; but in later times the production of this substance is not so much confined to those countries. France still produces considerable quantities of the article, and nearly the whole of the salt imported into this kingdom is from that country. Until the 19th of March, 1845, the duty on verdigris imported into this kingdom from France, was $1\frac{1}{20}$d. per pound weight; it was then subjected to an *ad valorem* duty of ten per cent., which was repealed in 1853.

The following table shows the quantity of verdigris chargeable with duty, imported into the United Kingdom during the six years ending the 5th May, 1846:—

	1841.	1842.	1843.	1844.	1845.	1846.
Cwt.,	1,340 ..	1,702 ..	1,816 ..	1,218 ..	897 ..	454

Of which there were retained for home consumption, and chargeable with duty, in—

	1841.	1842.	1843.	1844.	1845.	1846.
Cwt.,..	888 ..	1,576 ..	1,575 ..	1,129 ..	791 ..	677

During the years 1845, 1846, and 1847, there were imported from France alone, in—

Year.	Quantity imported chargeable with duty.	Declared value.	Duty received for home consumption.
1845,....	100,679 lbs.	£6,640	£227
1846,....	49,180 "	3,102	110
1847,....	76,200 "	4,971	170

The quantities of verdigris which entered the port of London during the corresponding four months, terminating the 5th of May, were, in—

	1845.	1846.	1847.	1848.
Cwt.,....	256	123	216	2

And the quantities retained for home consumption, and chargeable with duty, during the corresponding months above-mentioned, were, in—

	1845.	1846.	1847.	1848.
Cwt.,....	176	136	19	76

In 1852, the last year of the existence of the ten per cent. *ad valorem* duty, the imports of verdigris were four hundred and sixty-seven, and the exports seventy-two hundredweight. In 1853, the duty, as already stated, was entirely repealed; still, the imports are small, as large quantities of verdigris are prepared in England with pyroligneous acid and cider refuse. The foreign salt sells at a shilling per pound, and the English variety, made from cider refuse, at ninepence, as it has a greenish color, and is in every respect inferior to the former.

ACETATE OF THE OXIDE OF ETHYLE.—*Acetic Ether.*—This compound is prepared by distilling ten parts of anhydrous acetate of soda with seven parts of sulphuric acid and eight of absolute alcohol. The fluid which passes over is mixed with carbonate of soda till neutralized, the supernatant layer of aqueous acetic ether drawn off and agitated repeatedly with dry chloride of calcium, until that salt is no longer moistened with it; the solution is then distilled to procure the pure ether. It is a colorless mobile liquid, having an agreeable refreshing odor, and a pleasant taste; it burns with a yellowish flame, producing acid vapors. Its spec. grav. is 0·89 at 60° Fahr.; it boils at 165°, and is converted into vapor of spec. grav. 3·0634.

The liquid is soluble in seven parts of water, and in alcohol and ether in all proportions. Its composition is appended:—

	Atomic weight.	Per centage weight.
8 Eqs. of carbon,..........	48	54·55
8 Eqs. of hydrogen,........	8	9·09
4 Eqs. of oxygen,..........	32	36·36
1 Eq. acetic ether, ...	88	100·00

Formula:—$C_4\,H_5\,O,\ C_4\,H_3\,O_3$, or $C_8\,H_8\,O_4$.

Fig. 30 is a convenient form of apparatus for making acetic ether. A is a large flask, furnished with an air-tight cork, perforated with two holes, through one of which a safety or funnel tube, *d*, passes, and the other receives the tube, *c c*, bent at right angles as seen in the figure, through which the vapors pass to the condenser. The condenser, *g*, is a wide cylinder, having an aperture at the bottom, through which the bent end of the tube passes into a flask, *k*, placed beneath the cylinder to receive the distilled products. A cistern, E, supplies the cylinder, *g*, by the stopcock, *j*, with cold water, which is conducted to the bottom by the funnel pipe, *o*, and the partly-heated water passes off by the overflow pipe, *m*, into the vessel, N. Heat is applied to the flask by means of the spirit lamp, L.

Acetate of lead is a salt occasionally employed on the large scale, when making acetic ether; the proportions taken are, sixteen parts of dry acetate of lead to four and a half of absolute alcohol, and six parts of sulphuric acid, specific gravity 1·84. The sulphuric acid and alcohol are mixed in a vessel surrounded by ice, and the mixture, when cooled, is poured upon the finely-divided lead salt in the flask; the apparatus is adjusted, and a gentle heat applied at first, which is gradually increased towards the end of the distillation. The condenser is well cooled, and the receiver may be advantageously immersed in ice-cold water. The acetic ether obtained is rectified as before-mentioned.

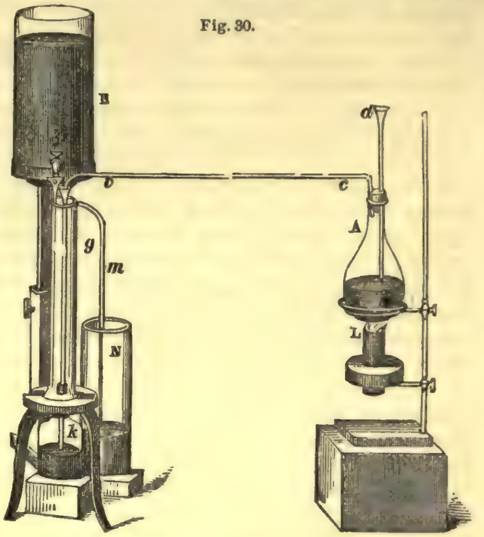


Fig. 30.

When this ether is poured upon chloride of calcium, combination takes place, and a crystalline mass results, from which, by the addition of a small quantity of water, acetic ether again separates. By digestion in a solution of potassa, acetic ether suffers complete decomposition; acetic acid unites with the alkali, and ether passes off: the same effect is produced when the ether is distilled with lime. Hydrochloric, sulphuric, and nitric acids decompose it, the ether uniting with these acids and liberating acetic acid. Pure acetic ether does not react on blue litmus paper, nor should it be colored by sulphide of hydrogen. It dissolves resins, sulphur, phosphorus, *et cetera*, like ether.

This compound is used as a constituent of several of the pharmaceutical preparations employed in medicine. From its power of dissolving resins and essential oils, it may be advantageously applied in the preparation of varnishes. The vinegar sold contains a small quantity of acetic ether, with the view, no doubt, of improving its taste and odor.

ACETATES OF IRON.—There are two acetates of iron: the *protoacetate* and the *sesquiacetate*.

Protoacetate of Iron may easily be prepared by dissolving sulphide of iron, or iron turnings, in acetic acid. In the former case, sulphide of hydrogen, and in the latter, gaseous hydrogen is evolved. This compound may likewise be obtained by decomposing a solution of the protosulphate of iron by acetate of baryta; but in this method there is formed a greater or less amount of sesquisalt, which can, however, be reduced to the state of protosalt by passing a stream of sulphide of hydrogen gas through the liquid. The protoacetate of iron crystallizes in prismatic crystals of a greenish color, which are very soluble in water, and readily pass into the state of basic acetate when exposed to the air. The composition of the dry salt is—

	Atomic weight.	Centesimal quantities.
1 Eq. of protoxide of iron, ...	36	41·379
1 Eq. of acetic acid, ...	51	58·621
	87	100·000

Formula:—$FeO, C_4H_3O_3$.

For commercial purposes, this compound is manufactured as follows:—Into a large cast-iron boiler or pot, a quantity of iron turnings, hoops, or nails, are introduced, and acetic acid—the crude pyroligneous acid from the distillation of wood—is poured in upon them. The strength of the acid is generally of 7° Twaddle, or spec. grav. 1·035. A temperature of 150° Fahr. is maintained till the solution of protoacetate of iron is obtained, of a spec. grav. 1·09, or 18° T., at 60° Fahr. During the solution of the iron much tarry matter separates, which is skimmed off, and the solution frequently agitated, to free it, as much as possible, from the tar. As soon as the above strength is gained, the solution is allowed to cool, for a further quantity of impurities to separate. When clean turnings are operated upon, the process of solution is completed in five to seven days. The hydrogen that is eliminated during the solution of the iron prevents the oxidation of the iron salt, as is seen in the subjoined equation:—

$$Fe + \underbrace{HO, C_4H_3O_3}_{\text{Acetic acid.}} = \underbrace{FeO, C_4H_3O_3}_{\text{Protoacetate of iron.}} + H.$$

Were any sesquisalt formed, the hydrogen, by combining with part of its oxygen, would again reconvert it to a protosalt.

Some printers dissolve the iron without the aid of heat, but this method is slow and unsatisfactory, for the deposit of tarry bodies on the iron prevents the action of the acetic acid; besides, from the long exposure to the air, some sesquisalt of iron is generated. The usual produce from one hundred gallons of acetic acid, and a proportionate quantity of iron turnings, is sixty to seventy gallons of acetate of iron, spec. grav. 1·090, or 18° T., and when this solution is reduced by the addition of water to a spec. grav. 1·060, it produces with madder a deep black.

The mordant is likewise made by decomposing a solution of sulphate of iron by acetate of lime; the proportions employed are the following:—

400 lbs. of protosulphate of iron—copperas—dissolved in 100 gallons of hot water, and the solution decomposed by 75 gallons of acetate of lime liquor, spec. grav. 1·08.

On agitating the menstruum, the decomposition is rendered complete; the clear liquor, which is siphoned off after subsidence of the sulphate of lime, possesses a density of 1·110.

When the liquor is not immediately required for use, it is apt to become oxidized, and deposits a basic salt, to prevent which some metallic iron is left in contact with the solution—this will combine with the oxygen of the sesquioxide. Sometimes, when a large quantity of pyroligneous matters deposits in the solution, the iron is prevented from acting by the coating of those matters which fall upon it; in such instances, a quantity of fine iron wire may be suspended in the liquid, and thus the formation of the basic acetate is prevented.

In some of the continental factories, the protoacetate of iron is manufactured by decomposing the protocarbonate of iron with acetate of lead: carbonate of lead precipitates, and the blackish supernatant liquor is the protoacetate of iron in a very pure state. It is kept from oxidizing by immersing in it some bright iron filings. The lead-salt formed repays the cost of the manufacture of the acetate. This method is, however, as yet limited.

SESQUIACETATE—PERACETATE OF IRON.—This salt is made by dissolving pure hydrated sesquioxide of iron in acetic acid, or by mixing solutions of sesquisulphate of iron and acetate of baryta in an iron pot, and agitating the liquid. Sulphate of baryta precipitates, and the clear liquid contains the sesquiacetate. It is an uncrystallizable, dark, brownish-red liquor, which, on evaporation, yields a deliquescent gelatinous paste. Like the acetate of alumina, it deposits an insoluble basic salt when heated, and hence its utility in dyeing operations. *Basic* acetate of the sesquioxide of iron is an insoluble yellow powder, precipitating out of the protoacetate which has oxidized in the air, and even out of the neutral sesquiacetate when kept for some time, especially if an alkaline salt be present. When pure, the composition of the sesquiacetate of iron is—

	Atomic weight.	Per cent.
1 Eq. of sesquioxide of iron, ...	80	34·344
3 Eqs. of acetic acid, ...	133	65·656
1 Eq. sesquiacetate of iron, ...	213	100·000

Formula:—$Fe_2O_3, 3\ C_4H_3O_3$.

Sesquiacetate of iron is manufactured chiefly for the use of dyers, the salt being rarely employed by the calico-printer.

Where the dyer requires uniform grounds, he cannot as well employ the protosalts of iron, for when cotton is impregnated with such a solution as copperas or the protoacetate of iron, while drying it attracts oxygen from the air, and the sesquioxide of iron, or a basic salt, collects more in those parts not yet dry, and will, of course, produce darker spots in the dye-bath. It is, therefore, better to prepare an acetate of the sesquioxide of iron at once, either by pouring acetic acid repeatedly over iron turnings for several weeks, in vessels exposed freely to the air, or, still better, by double decomposition with acetate of lead or acetate of lime. For this purpose, dissolve one pound iron-alum in half a gallon of water, add one pound acetate of lead, stir the liquor well, let it settle, and decant or filter. The solution made from iron-alum will not keep long, as it gradually deposits an insoluble basic salt from the presence of sulphate of potassa, while that made from sesquisulphate of iron will retain its properties for a great length of time; on the other hand, iron-alum is more convenient in use, from its containing known quantities of sesquioxide, and the difficulty abovementioned may be obviated by preparing only the quantity required for immediate use.

The sesquiacetate of iron may also be made from sesquisulphate of iron and acetate of lead. As the sesquisulphate of iron is not so uniform in composition as the iron-alum, it may be well to ascertain how much oxide of iron and sulphuric acid it contains, in order to know what quantity of acetate of lead to employ in its decomposition. For this purpose, weigh out one hundred grains, which is about half an equivalent of dry and pure sesquisulphate; dissolve in water, and filter; add two hundred and eighty-five grains crystallized acetate of lead—half of three equivalents—dissolved in water, filter and weigh the precipitate, which is sulphate of lead: every seventy-six grains of this sulphate of lead require ninety-five or more—safely, ninety—grains of acetate of lead to insure sufficient decomposition. Calling grains, pounds, the operation may then be conducted on a large scale. The excess of acetate of lead in the acetate of iron mordant, may be ascertained by diluting a little of the clear liquor with water, and adding a few drops of sulphuric acid; if it becomes cloudy, there is an excess of acetate of lead, which may prove injurious to colors, but this is easily obviated by adding a little more sesquisulphate of iron, until the clear liquor is no longer affected by sulphuric acid. For the ordinary operations of the dyer, it may not be necessary to decompose all the sesquisulphate of iron; but for printing, and particularly for full russets, the whole salt should be sesquiacetate of iron, otherwise some of the sulphate would disappear in washing the goods, while they may be fully charged with basic acetate of iron, which cannot be removed by water.

The acetates of iron are employed in woollen dyeing, to produce blue with ferrocyanide of potassium—yellow prussiate; in cotton dyeing and printing, and in silk dyeing, for blacks, russets, *et cetera;* the protoacetate with madder, for violet; the same, together with red liquor, for brown; in dyeing hats and furs black; for blackening leather, wood, *et cetera.* Some prefer the protoacetate, because, by the oxidation of the iron subsequent to dyeing, the colors are more resistent; but greater uniformity of the ground is insured by the use of sesquiacetate.

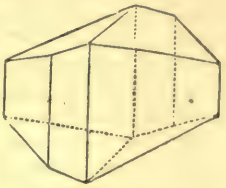
The sesquiacetate of iron, containing protoacetate, may also be conveniently made by pouring pyroligneous acid on iron turnings in a series of vessels placed obliquely one above the other—as will be more particularly described under acetate of lead—suffering the acid to remain the same length of time in contact with the metal, and repeating the operation twice, or until the acid is saturated.

Pyroligneous acid—crude wood vinegar—is now almost universally employed for the manufacture of the protoacetate and sesquiacetate of iron.

ACETATE OF LEAD.—*Sugar of Lead; Salt of Saturn,* of the old chemists.—Oxide of lead unites with acetic acid in various proportions, the most important of those combinations being the neutral acetate, known in commerce under the above names. It is used to a great extent in the calico-printing business, and likewise in dyeing, for the preparation of other compounds employed in those trades, and occasionally as a medicinal agent, and in pharmaceutical preparations.

It may be prepared by digesting pure oxide of lead in dilute acetic acid, or by exposing thin sheets of lead in a confined chamber to the action of the vapor of acetic acid; they become corroded, and there is formed a mixture of carbonate and acetate of lead on the surface of the sheets, which is scraped off, and dissolved in a slight excess of acetic acid. On evaporating this solution, the acetate of lead crystallizes in acicular masses, if the hot solution be set aside to cool rapidly; but if the evaporation be conducted slowly, the crystals are truncated and flattened quadrangular and hexahedral prisms—Fig. 31—derived from a right rhombic prism. The crystals are permanent in the air, but are apt to effloresce and become anhydrous if the temperature ranges between 70° and 100° Fahr. Anhydrous acetate of lead is soluble in boiling absolute alcohol, and is deposited again in hexagonal plates on the slow cooling of the spiritous solution. Acetate of lead has a sweet astringent taste, is soluble in less than three and a half times its weight of boiling water, and in nearly the same quantity of cold water. PAYEN states, that a hundred parts of water at 60° Fahr., dissolve fifty-nine parts of the crystallized acetate of lead. The crystallized salt is fusible in its water of crystallization at 130°, boils at 212°, and after elimination of the water solidifies into a lamellar mass.

Fig. 31



On raising the temperature higher, the substance fuses, and evolves all the compounds usually obtained in the destructive distillation of the acetates of the heavy metals, leaving a residue of highly pyrophoric metallic lead, in a very minute state of division, with some charcoal.

A slight decomposition occurs when the neutral salt is exposed to an atmosphere of carbonic acid—carbonate of lead being formed; the portion of acetic acid thus liberated protects the remainder from further change.

The anhydrous acetate is composed of—

	Atomic weight.	Per centage weight.
1 Eq. of oxide of lead,	112	68·71
1 Eq. of acetic acid,	51	31·29
1 Eq. of acetate of lead,	163	100·00

and the composition of the crystallized salt is—

1 Eq. of oxide of lead,	112	58·95
1 Eq. of acetic acid,	51	26·84
3 Eqs. of water,	27	14·21
1 Eq. of crystallized acetate of lead,	190	100·00

Formula:—$PbO, C_4H_3O_3 + 3HO$.

BROWN ACETATE OF LEAD.—The distilled pyroligneous acid is saturated with litharge in a tub, and the muddy solution ladled out into a large tun to settle; the solid matter readily subsides, and the clear solution is transferred into a pan of malleable-iron, but which may be made of cast-iron, and six feet long by four feet broad. The solution is brought to the boiling point in this pan, then allowed to settle; it is next transferred into a large hemispherical pan, capable of holding about three hundred or four hundred gallons, where it is evaporated down to about crystallizing strength. When the solution has become dense enough to crystallize, about three times its bulk of water is run in upon it whilst boiling, the solution being constantly stirred. By this treatment a considerable quantity of impurities is disengaged, which may be skimmed off as fast as they rise to the surface; after they are removed, the evaporation goes on as before. If the solution be still too much colored, another dose of water must be given. A little practice soon enables the operator to know when the evaporation should be checked. The ordinary method is, to rinse a ladle—which is used to skim off tar from the solution —through the liquid, and observe how many drops fall from it before the solution takes a stringy appearance; if only ten or twelve fall, then it is sufficiently strong. The liquid is now ladled out into malleable-iron pans to crystallize; the pans are five feet long by three feet broad, and about six inches deep, the sides being bevelled or sloping outwards from the bottom. After the crystals have become sufficiently firm, the sugar of lead is taken out, by inverting the pan on a cloth. The pots used in the above process are heated only at the bottom.—*A. P. Halliday.*

WHITE ACETATE OF LEAD.—This is prepared by dissolving litharge in acetic acid. The acetic acid is introduced into a vessel, the litharge added by degrees, and the menstruum kept in brisk commotion after each addition, until the solution only slightly reddens litmus paper; a quantity of water, equal to about one-half of the acid employed, is then run into the lead solution; heat is applied, and the mixture slowly evaporated for about twelve hours, or until it has acquired a density of about 1·500. During evaporation, any impurities which rise to the surface are skimmed off, and when the solution has acquired its proper gravity, it is drawn into the crystallizing pans. When the crystals have become sufficiently hard to allow of their being taken *en masse* from the crystallizers, they are drained and placed on wooden racks in the drying-house, and, when dry, cleaned and broken up into fragments for the market.

The mother liquor, which contains neutral and basic acetates of lead and other metallic salts, may either be treated with vinegar, evaporated, recrystallized, and the residue employed as washings in subsequent operations; or it may be decomposed by carbonate of soda or lime, and used as carbonate of lead; or dissolved in acetic acid, and the supernatant acetate of soda or lime recovered.

Vessels used in this manufacture are, in most cases, of lead. In Wales, the mixing pans are of lead, three quarters of an inch thick, seven feet long by four and a half feet wide, and one foot deep. These pans are set on iron plates over arches, and the fireplaces are outside the building, in order that the acetate may not be darkened by the sulphurous vapors from the coal. The crystallizing pans are of wood, lined with thin copper, and are about four feet long by two feet wide, and from six to eight inches deep, sloping inwards at the edges. At Pitchcombe, the mixing and crystallizing vessels are both of copper, having a strip of lead soldered down the sides and across the bottom of the vessel, to render the metals more electro-negative, whereby the acetic acid is prevented acting on the copper. Very great care is requisite in the drying of the sugar of lead; the temperature of the desiccating-house should not exceed 90° Fahr. In Wales, the heated air of a stove, placed outside the drying-house, is conveyed through pipes passing round the interior; at other places, steam heat is the agent for this purpose, which is much to be preferred on account of its being more easily regulated.

That the manufacturer may the better judge of the success of his operations from the amount of the product obtained, the following will serve as a precedent:—One hundred and twelve pounds of good Newcastle litharge should produce a hundred and eighty-seven pounds of sugar of lead, when treated with a hundred and twenty-seven pounds of acetic acid of spec. grav. 1·057, but not more than a hundred and eighty pounds are obtained in practice. The quantity produced, given in URE's Dictionary of Arts and Manufactures, and in other works, is evidently a misprint, being almost three times the weight of the litharge employed. A manufacturer of sugar of lead would indeed be fortunate who could obtain such a return. In a factory in Wales, a ton of Welsh litharge produces, with the acid obtained from one ton of acetate of lime, from twenty-eight to thirty hundred weight of sugar of lead; and in another manufactory, one ton of best Newcastle litharge, with the acid from one ton and a half of acetate of lime, produces thirty-three hundred weight of the lead salt.

The following process with metallic lead, recommended first by BERARD, is easily executed, and is said by RUNGE to yield a good product with great economy. Granulated lead, the tailings in the white lead manufacture, *et cetera*, are put in several vessels—say eight—one above the other, upon steps, so that the liquid may be run from one to the other. The upper one is filled with acetic acid, and after half an hour let off into the second, after another half hour into the third, and so on to the last or eighth vessel. The acid causes the lead to absorb oxygen rapidly from the air, evolving heat, so that, when the acid runs off from the lowest, it is thrown on the uppermost vessel a second time, carries off the acetate of lead formed, and after passing through the whole series, the solution is so strong that it may be evaporated at once to crystallize. There are two points of importance in this manufacture. Whatever method may be pursued, a strong acid is to be employed, that less of it may be lost in concentrating the liquid, and, likewise, to economize time, and retain an acid reaction in the liquid, by which the formation of a basic salt is prevented.

It may not be amiss to call attention here to a process, patented about ten years since, for preparing acetate of lead and other acetates. It consists in employing the acid in the state of vapor, to act upon the bases, instead of using it in the liquid form. A vessel is provided of adequate capacity for the quantity of acetate required, and constructed of such material as will not be readily destroyed by the acid. The top of this vessel is closed hermetically by a cover, fastened down by any convenient means, and in the lower part of the vessel is placed either a minutely-perforated false bottom, or a coiled tube of several convolutions, minutely perforated, to permit vapor to permeate freely. To prevent the loss of acid, there is also placed, at different degrees of elevation, several perforated diaphragms, similar to the false bottom just mentioned, on each of which is spread a layer of litharge, after which the cover of the vessel is to be accurately closed. By means of an ordinary distillatory apparatus, liquid acetic acid—strong or weak, pure or impure—is converted into vapor, which is then conducted by means of a pipe into the convoluted and perforated one before mentioned, or between the real bottom of the vessel and the perforated false bottom; hence the vapor, passing through the numerous perforations of the false bottom and diaphragms, diffuses itself throughout every part of the vessel, its acid entering into combination with the base employed, and forming the acetate, which falls to the bottom of the vessel, and in its descent meets with the ascending streams of vapor, the acid of which renders it perfectly neutral; meanwhile the more aqueous parts of the vapor become liberated, and maintaining their temperature ascend, and in their passage through the successive layers of the base are deprived of their remaining acid. The vapor, thus reduced to simple steam, is allowed to escape through one or more pipes at the top of the vessel, and as this still maintains a boiling temperature, it is conducted through a worm to evaporate the acetate or mother liquor. Distillation of the acid is continued until the acetate in the vessel has acquired the proper degree of concentration for crystallization, which is easily ascertained by examining a small quantity drawn off by a tap at the bottom of the vessel, through which the whole contents are discharged when the operation is completed. As the work draws to its close, nearly all the base having combined with the acid, the vapor issues out of the vessel charged with a certain portion of acid; and that no loss may be sustained by its escape into the atmosphere, it is conducted into another vessel prepared like the first-mentioned, but charged superabundantly with the base, to take up every particle of the acid issuing from the first vessel, until the contents of the latter are converted into acetate of lead. As the temperature of the solution of the acetate can never exceed that of the vapor, the crystalline product is of fine quality.

ACETATE OF LIME.—This salt is formed when pure carbonate of lime is dissolved in acetic acid. The action is as follows:—

$$\underbrace{CaO, CO_2}_{\text{Carbonate of lime.}} + \underbrace{C_4H_3O_3, HO}_{\text{Hydrated acetic acid.}} = \underbrace{CaO, C_4H_3O_3}_{\text{Acetate of lime.}} + HO + CO_2.$$

According to **Pelouze**, the carbonate of lime does not dissolve in the monohydrated acid. The pure salt crystallizes in silky, acicular prisms, of a bitterish saline taste, which effloresce when heated to 212°. It is soluble in water and alcohol. The dry salt has the property of being phosphorescent in the dark, when triturated at 226° Fahr. Its composition is—

	Atomic weight.	Per centage weight.
1 Eq. of lime,	28	35·4
1 Eq. of acetic acid,	51	64·6
1 Eq. of acetate of lime,	79	100·0

When speaking of the preparation of pure acetic acid from wood acid—page 28—a curtailed account of the production of this compound was given, as likewise for the acetate of soda. A modification of the method there mentioned, for the production of a purer article for the market, will be here considered. The following is the mode of working in large factories:—The crude acid liquor from the distillation of wood, after separating the pyroxylic spirit, is either distilled or run off into other convenient vessels, according as the *grey* or *brown* acetate is to be procured. In either case, the subsequent procedure is the same. Five hundred or one thousand gallons of the liquid are run off into wooden or iron vessels, of suitable capacity, and powdered chalk or slacked lime added, till a slight excess remains undissolved, and the whole agitated briskly for some time, in order to insure complete combination. The menstruum is then allowed to rest at a temperature of 150°, till the excess of lime and tarry compounds subsides, when the clear supernatant liquid is siphoned off into the evaporating pans, which, in most factories, are wooden vessels lined with lead, and heated by coils of iron pipes placed within them, through which steam passes; in some factories they are shallow, and made of sheet-iron, and placed together directly over the fire. The solution of the lime salt is kept simmering, and briskly agitated during the evaporation, and the scum of tarry impurities that agglomerates at the surface must be skimmed off. Acetate of lime, as soon as it begins to form, is separated from the liquor by the skimmers, and thrown into wicker baskets suspended over the pans, so that the solution draining from the salt may not be allowed to cool. The subjoined practical results were obtained by the use of three sheet-iron pans of about eighteen inches in depth, each capable of containing four hundred and fifty gallons of the solution.

	Number of gallons of liquor evaporated.	Producing of dry acetate of lime,
In the first six days, of twenty-four hours each,	7,020	78 cwt.
In the second six days, of twenty-four hours each,	8,060	92 "
In the third week of six days, of twenty-four hours each,	7,000	78 "

Two of the pans contained *brown* acetate of lime liquor.

The yield of acetate here mentioned is of course dependent upon the variety of wood submitted to distillation, as also upon its state of dryness and the proper regulation of temperature. That part of the process which demands the greatest attention is the *drying*, as on the proper execution of it the success of the operation in a great measure depends. Several methods are in use for drying the lime salt, some of which cannot prove efficient to the manufacturer. In some factories, the salt is dried by spreading it in thick layers on the top of the brickwork surrounding the carbonizing retorts and steam-boilers; but in large works, where ten, twelve, or fifteen thousand gallons of liquor are evaporated weekly, the products could not be dried in this way. In well-regulated factories, it is customary to have a drying-house apart for the purpose, and where lime is burned on the premises the heat from the kilns is advantageously applied to drying the lime salt, by conducting it through flues in the floor of the drying-house. As a rule, there should be a drying-house attached to every factory, for exsiccating the acetates, as the want of it may entail the loss of the whole product of the distillation of the wood, so far as the acetic acid is concerned. The following description of a drying-furnace is taken from an article on wood vinegar, and the manufacture of some of the acetates, in the Pharmaceutical Journal:—

The drying apparatus is a simple wind furnace, seven or eight feet long, and four and a half feet broad, built of brick. At six inches above the ground is the ash-pit, eight inches broad and twelve inches high, which is covered with a grate of bricks. The fireplace is twenty inches high, and ten inches broad, at the grate; over it is an arch of bricks, so that the fire cannot play on, and heat very highly, the iron drying-plate lying on the side of the hearth. The space below the drying-plate is separated from the hearth by a partition of bricks, three or four inches high; twelve inches above the outlet of the hearth is a layer of iron bars, one and a half to two inches from each other, and upon these is deposited the drying-plate. This consists of cast-iron, a quarter of an inch thick, and is formed according to the size of the furnace. Round the plate the furnace is built up to the height of ten inches on the side of the front wall, leaving room for doors, which may be calculated at two and a half feet. These doors are two, one above the other, through which the whole interior of the furnace can be inspected. They are formed of plate-iron, and have in their middle a sliding door, to admit of the exit of the vapor of the acetate of lime, and of some ventilation. A wall built at the end of the plate, or a clay partition, separates the whole of the drying-plate from the chimney. In the walls of the furnace, iron bars are fixed, and upon these a second drying-plate covers the drying space. This plate, as it does not come in contact with the fire, may consist of good iron, or of clay. Above this drying space another is formed by means of the chimney. The heat passes as well under as above the drying space, thence into the chimney, which is situated at the side of the furnace, and can be shut by a valve. The prevailing temperature in the drying-room is 167° to 235° Fahr. Turf forms the best material for fuel, as it does not burn rapidly, and produces a steady and equal temperature.

When the furnace is equally heated to the proper temperature, the fire is slackened. If wood be employed for fuel, the sliding door should be opened at the commencement, in order to allow the moisture to escape. The salt is transferred from the baskets over the evaporating pans to the drying-plate, and spread out to the depth of two inches, and after the first portion has become somewhat dry, the depth is increased to four or five inches; the heat, as already mentioned, is kept up for twenty-four hours, during which the salt is repeatedly turned. Subsequently, when the mass appears to be becoming dry, the temperature is raised to 257° Fahr., in order to expel every trace of water; in doing so, however, care must be taken that it is gradually applied, and that no fume is expelled from the acetate of lime, for then decomposition of the salt would be taking place; neither should any spark of fire be suffered to come in contact with the dried salt, since it possesses the characteristic property of igniting and burning like sugar of lead. During the drying by this means, the tarry and oleaginous matters with which the acetate is impregnated are decomposed, a black charcoal remaining, which appears in streaks through the dry mass. On dissolving the desiccated acetate of lime in three parts of hot water, and filtering through coarse animal charcoal or gravel, the charcoal and decomposed carbonaceous matters of the salt are retained; and the solution, upon evaporation and subsequent torrefaction of the residuary matter, affords a very pure and nearly colorless product The average yield of this salt from one ton of wood, is one hundred and forty pounds.

ACETATE OF MANGANESE.—This compound is prepared by dissolving pure carbonate of manganese in acetic acid, evaporating the solution, and crystallizing. The crystals are of the rhombic prism, and occasionally in plates of an amethystine color; they are permanent in the air, soluble in alcohol, and in about three and a half times their weight of cold water. The composition of the dry salt is—

	Atomic weight.	Per centage composition.
1 Eq. of protoxide of manganese,	28	41·38
1 Eq. of acetic acid,	51	58·62
	79	100·00

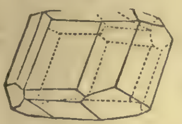
Formula:—$Mn\,O, C_4\,H_3\,O_3$.

On the large scale, this salt is manufactured by precipitating a solution of the sulphate of manganese by one of acetate of lime, and agitating the liquor to decompose the whole of the sulphate of manganese.

It happens that a portion of the manganese salt is not acted upon by the acetate of lime, and to effect the complete decomposition a concentrated solution of acetate of lead is employed towards the end. The mixed precipitate of sulphate of lime and lead is filtered off, and the filtrate evaporated and crystallized, or used directly, if deemed necessary. The best acetate of manganese is made by adding to four parts of sulphate of manganese in three parts of water, seven parts of crystallized acetate of lead dissolved in three parts of water, agitating the solution, and drawing off the clear liquor for use.

Acetate of manganese is used in dyeing and calico-printing, to give a brown color to fabrics. Its principle of action depends upon the oxidation of the protoxide. The cloth is well steeped in a concentrated solution of the acetate of manganese, and printed; it is then passed through a bath of hypochlorite of lime—bleaching powder—which converts the protoxide of manganese into a higher oxide, producing a brown color on that which, previous to the immersion in the bleaching or chloride of lime solution, was colorless.

Fig.32.



ACETATE OF SODA.—This salt is formed by dissolving carbonate of soda in acetic acid, evaporating the solution, and setting the liquor aside to crystallize. The crystals are oblique rhombic prisms—Fig. 32—soluble in three parts of cold, in a less quantity of boiling water, and in five of alcohol.

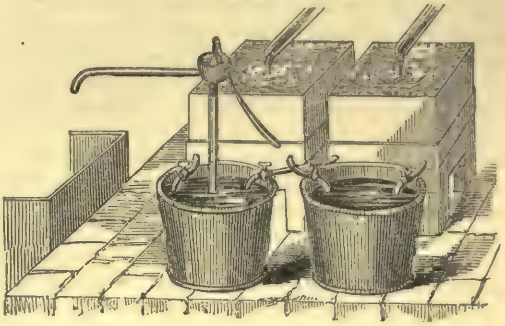
The composition of the dry salt is appended:—

	Atomic weight.	Per centage weight.
1 Eq. of soda, ...	31	37·8
1 Eq. of acetic acid, ...	51	62·2
1 Eq. of acetate of soda, ...	82	100·0

Formula:—$NaO, C_4H_3O_3$.

On the large scale, the manufacture is carried out in the following way:—A filtered solution of the common acetate of lime is precipitated by one of sulphate of soda, at 98° or 100° Fahr., till the whole of the lime is thrown down as sulphate. The strength of the solution of the lime-salt is 1·116, and of the soda solution 1·250; or the sulphate of soda may be added in powder, and the whole well agitated until no further precipitation of sulphate of lime takes place, using the precaution, however, of adding the sulphate of soda sparingly, so as to prevent its excess. The mixture, after thorough agitation, is drawn off into a deep vessel and allowed to repose, and when the precipitated sulphate of lime has completely settled, the clear liquor is siphoned off and conducted to the evaporating pans for crystallization, the lime-salt remaining being washed with successive portions of water, till the whole of the acetate of soda is separated. The first washings may be added to the strong solutions in the evaporating pans, and the others retained for dissolving fresh portions of acetate of lime for subsequent decomposition. Occasionally, the solution from the decomposing vessel is filtered, and the precipitate washed in the following manner:—One or two backs are provided, according to the size of the factory; these are placed over two cisterns, each cistern being connected with both the backs by pipes, branching from the latter to both cisterns; by means of a stopcock in those connecting pipes, the communication with either back may be cut off at will when required, as seen in Fig. 33. The backs are either square or circular, having false bottoms, in which are filters of stout twilled flannel. The charge from the decomposing pan is run on to one of the backs and filtered, till the whole of the strong liquor has passed into one of the cisterns; the connection with this cistern is then cut off, and when the washing of the residue commences, the pipe communicating with the other cistern is open, which conducts the washings into it. A fresh charge may be introduced into the second back, and the pipe reaching to the cistern holding the strong liquor opened, and thus the strong liquor is always obtained by itself ready for evaporation. Another advantage is, that while the residue in one back is in the course of being washed, the other may be filtering off strong liquor. The washing is continued till the percolations are nearly tasteless, and the residuary sulphate of lime dug out of the filters with wooden spades—iron spades cannot be used, as they are apt to cut the filters. Dilute solutions from the washing may be employed to dissolve fresh quantities of the acetate of lime for decomposition, by means of the soda-salt. The acetate of soda liquor is then pumped from the cisterns into the evaporating pans, which should be so constructed as to offer as much heated surface as possible, so that one man can keep their contents in brisk agitation. As the evaporation draws to a termination, much care and skill are required in keeping the liquefied salt well stirred, so as to have every part equally under the influence of the heat, and to prevent decomposition of the whole mass. The temperature should never rise higher than 500° Fahr., and in drying the acetate of soda, 450° to 470° is the temperature that should be applied. White fumes passing off from the fused mass are indicative of the decomposition of the salt, and if the fire be not checked immediately, nothing will be left but carbonate of soda and charcoal. If the purified acetate of lime be employed, the acetate of soda, obtained by dissolving the above product in water, evaporating and crystallizing, will be quite pure. For this purpose, the fused salt is dissolved in twice its weight of water, the solution filtered through filter-bags, and the liquor evaporated till it acquires a spec. grav. of 1·50, when it is drawn off to the crystallizing pans. These may be of boards lined with four-pound lead, four feet long, two feet wide, and nine inches deep. The concentrated solution of the salt is left in the pans for two, three, or four days, according to the temperature of the room, till a crop of crystals are produced; the crystals are separated and deposited in baskets, where they are allowed to drain, and the mother liquor remaining is returned to the evaporating pan, or it is employed to dissolve fresh quantities of the crude salt. The crystals are washed with cold water, to separate any adhering mother liquor, and placed on shelves to dry, when they are ready to be packed. The washings may be added to the mother liquor, and used as above.

Fig. 33.



The Pharmaceutical Journal gives the following mode for the purification of this salt:—The acetate of soda is dissolved in a large cylindrical lead vessel, heated by shooting steam into it. When the solution is completed, it may be run through a flannel filter into the top of a course of steamers, furnished with coils of three-quarter inch lead pipe. These vessels are made of four-pound sheet-lead, cased in boards; the best size is about twenty-four feet long, four feet wide, and nine inches deep. The pipe should be coiled from one end of the pan to the other, and should go up and down two or three times. Too much pipe cannot be used, as the rapidity of the evaporation depends upon the quantity employed. As the evaporation proceeds, the liquor ought to be siphoned from the top to the second, and afterwards to the third steamer, and thus room made for more bulky weak liquor from the dissolving lead: when a pellicle appears on its surface, it should be siphoned off into the crystallizers, and allowed to rest for two or three days, when beautiful crystals in oblique rhombic prisms are obtained. If very large crystals are required, the coolers are immersed in sawdust, or some other non-conducting material, and a longer time is allowed for them to form. In general cases, the amount of acetate of soda obtained from one ton of the lime-salt, ranges from twenty to twenty-two hundred-weight, but frequently a less quantity results. The impurities present in acetate of soda, are sulphate of soda and acetate of lime; the presence of the latter is caused by the imperfect decomposition of the acetate of lime by sulphate of soda, and of the former by a too abundant use of that salt in decomposing the acetate of lime. The sulphate of soda is separated by skimming off the crystals of this salt, which form before those of the acetate of soda; but the acetate of lime cannot afterwards be got rid of, and is injurious in *running the crystals*, as the workmen term it; that is, it prevents crystallization. The most economical method for manufacturing the acetate of soda, would be to neutralize the crude acid from the distillation of wood with sulphide of sodium; but the sulphide of hydrogen, given off in such enormous volumes, is a paramount objection to this method. In other factories, instead of evaporating the acetate of soda to dryness, and subsequently torrefying the dry mass, the purification is effected by repeated crystallizations and filtrations of the solution through animal charcoal, previously washed with hydrochloric acid.

The solutions recommended by **Mitscherlich** for this purpose, should have a density of 1·116 for the acetate of lime, and 1·24 for the sulphate of soda; when they are stronger, the impurities do not so readily subside.

ACETATE OF THE PROTOXIDE OF TIN.—This salt is also employed in calico-printing, to give light spirit colors to cloth. The process of manufacture is nearly the same as for the preceding. The proportions taken are, one hundred and three parts of crystallized protochloride of tin, dissolved in water, and one hundred and ninety parts of crystallized acetate of lead. It may likewise be prepared by dissolving protoxide of tin, or metallic tin, in acetic acid. In technical operations, the first method is usually followed. On evaporating the filtered solution to a syrupy consistence, and adding alcohol, the salt crystallizes in colorless transparent needles, which have a great tendency to oxidize, if at all exposed to the air.

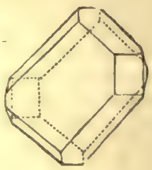
Another recipe is to dissolve thirty pounds of acetate of lead in forty gallons of boiling water, and add 18¾ pounds of crystals of the tin salt; the mixture is well stirred, allowed to settle, and the liquor filtered or siphoned off for use into casks or vessels, protected as much as possible from contact with the air. Some makers prefer to prepare the salt when immediately wanted for use.

ACETATE OF ZINC.—This salt may be prepared by dissolving metallic zinc, or oxide of zinc, in acetic acid, or by the decomposition of its sulphate by acetates of lime or lead, similar to the acetate of manganese—the decompositions, in these instances, being represented in the annexed equations:—

$$Zn + C_4H_3O_3, HO = ZnO, C_4H_3O_3 + H.$$
$$ZnO + C_4H_3O_3, HO = ZnO, C_4H_3O_3 + HO.$$
$$ZnO, SO_3 + PbO, C_4H_3O_3 = ZnO, C_4H_3O_3 + PbO, SO_3.$$

The acetate is obtained, in the first two instances, simply by evaporation, and in the latter, after agitating the mixture, filtering and evaporating the menstruum, the salt crystallizes in flexible, opalescent, six-sided tables—Fig. 35—which effloresce slightly in the air. The composition of the dry salt is—

Fig. 35.



	Atomic weight.	Per centage weight.
1 Eq. of oxide of zinc, ...	40·5	44·27
1 Eq. of acetic acid, ...	51·0	55·73
1 Eq. of acetate of zinc, ...	91·5	100·00

Formula:—$ZnO, C_4H_3O_3$.

According to **Schindler**, the crystals contain three atoms of water when deposited from cold solutions, and only one atom when they are formed from concentrated hot ones. Technically, the best recipe is to dissolve four parts of the sulphate of zinc, and seven and a half parts of acetate of lead, each in three parts of hot water, mixing the solutions, agitating, and, after the sulphate of lead has deposited, drawing the clear liquid off to crystallize.

ALCOHOL.—*Alcool*, French; *Alkohol* or *Weingeist*, German; *Spiritus Vini Alcoholisat.*, Latin.—A preparation of antimony used to be designated by this name—the oriental females still use it for painting their eyebrows. The appellation was afterwards given to other fine powders, and to highly-rectified spirits.

There is no evidence of the ancients being acquainted with alcohol or ardent spirits; in fact, there is every reason to believe the contrary, and that distillation was quite unknown to them. This fact is more apparent from the method followed by **Dioscorides** to obtain quicksilver from cinnabar—sulphide of mercury: he mixed the cinnabar with iron filings, put the mixture into a pot, to the top of which a cover of stoneware was luted; heat was applied, and when the process was terminated, the mercury was found adhering to the side of the cover. The children of the nineteenth century might well laugh at the docimastic notions of the old philosopher. **Dioscorides**, however, was not without penetration and judgment, but he was unacquainted with the method of adapting a receiver to his pot, otherwise he never would have proceeded as above recounted. Another strong corroboration of the fact, that alcohol was unknown in former times is, that neither the poets, historians, naturalists, nor medical men, make the slightest allusion to ardent spirits—a circumstance which would not have happened had these liquids been applied to even a hundredth part of the uses made of them by the moderns.

In the strict chemical sense, the term *alcohol* is employed as a generic word for a class of bodies belonging to the same type, or framed upon the same principle. Just as *salt*, originally applied to chloride of sodium, or the condiment with which we season our food, is now extended to a class of bodies often destitute of savor; as *metal* designates several substances which do not possess either the malleability, the specific gravity, or the power of resisting heat, which characterized those from which the term was borrowed; or as *acid* appertains to many compounds having neither a sour taste nor any caustic properties; so *alcohol* indicates a class, some members of which, far from being volatile, are not even liquid, and, instead of igniting easily, require a pretty elevated temperature for kindling. The following are three properties by which the genus alcohol may be recognized:—

1. When subjected to the action of oxidizing bodies, it loses two atoms of hydrogen, sometimes replaced by two of oxygen, when it is converted into an acid, and in other cases eliminates the same without acquiring oxygen in its stead, when it produces an aldehyde.

2. Under the influence of substances having a strong affinity for water, such as sulphuric acid, chloride of zinc, and phosphoric acid, it has a strong tendency to lose two equivalents of water, and to be transformed into carbide of hydrogen, or else to split into water and ether.

3. Exposed to the action of chlorine, aldehydes are formed from it, owing to the abstraction of two atoms of hydrogen.

In the case of the alcohol produced from vinous fermentation, which one may call wine-alcohol, there is a body consisting of the oxide of a carbide of hydrogen, having the proportion of four equivalents of carbon to five of hydrogen, and united to an atom of water.

This compound may be converted into acetic acid by the abstraction of two equivalents of hydrogen, and the addition of two of oxygen, through the agency of potassa, and also by a variety of other bodies.

The effect of the decomposition would be as under:

$$\begin{array}{lr}
\text{Alcohol, }\dots\dots\dots\dots\dots\dots & C_4\,H_6\,O_2 \\
\quad\text{Minus, }\dots\dots\dots\dots\dots\dots & H_2 \\ \hline
\quad\text{Equal, }\dots\dots\dots\dots\dots\dots & C_4\,H_4\,O_2 \\
\quad\text{Plus, }\dots\dots\dots\dots\dots\dots & O_2 \\ \hline
\text{Acetic acid, }\dots\dots\dots\dots\dots\dots & C_4\,H_4\,O_4
\end{array}$$

and which, by the continuation of the action of the potassa, is broken up into—

$$\left.\begin{array}{ll}
\text{Carbonic acid, }\dots\dots\dots\dots & C_2\quad O_4 \\
\text{And light carbide of hydrogen, } & C_2\,H_4
\end{array}\right\} = \underbrace{C_4\,H_4\,O_4}_{\text{Acetic acid.}}$$

According to DUMAS, this decomposition is occasioned by the affinity of hydrate of potassa for carbonic acid, inducing, in the first instance, the resolution of the alcohol into that compound through the decomposition of the water of the alkali; hydrogen is evolved, whilst its oxygen carries off the hydrogen of the alcohol, thus—

$$\underbrace{2\,(C_4\,H_6\,O_2)}_{\text{Alcohol.}} + \underbrace{16\,(K\,O,\,H\,O)}_{\text{Potassa.}} = \underbrace{(K\,O,\,C_4\,H_3\,O_3)}_{\text{Acetate of potassa.}} +$$
$$\underbrace{4\,(K\,O,\,C\,O_2)}_{\text{Carbonate of potassa.}} + \underbrace{11\,K\,O}_{\text{Potassa.}} + \underbrace{9\,H\,O}_{\text{Water.}} + \underbrace{16\,H.}_{\text{Evolved.}}$$

The Editor finds, that when alcohol and potassa are left at rest in a stoppled bottle for some weeks, the menstruum acquires a pinkish color; and when this mixture is distilled, acetate of potassa is found in the residue. Is the change owing to the decomposition of the water, as stated by DUMAS, or to the absorption of oxygen from the air?

$$2\,(C_4\,H_6\,O_2) + 5\,K\,O + 7\,O = K\,O,\,C_4\,H_3\,O_3 + 4\,(K\,O,\,C\,O_2) + 9\,H.$$

Other carbides of hydrogen, known or supposed to exist, give rise to similar combinations with oxygen and water, each of which would be regarded as the hydrated oxide of the particular compound radical; and hence they, in like manner, are called, by analogy, the *alcohols* of the bases to which they are allied, since they possess the properties just mentioned as characteristic of the class.

Alcohol is one of a numerous class of homologous bodies derived from carbide of hydrogen radicals, each differing in their composition by a definite number of elements of carbon and hydrogen. In giving rise to those bodies, it is found that the same number of equivalents of oxygen is appropriated by their respective radicals; and from this relation and their similarity in properties and composition, alcohol, as a general term, has been applied to the series: the propriety of the term will be seen on comparing the formulæ of a few of them:—

Radicals.		Oxides of radicals, or ethers.	Hydrated oxides of radicals, or alcohols.
Methyle, ……	$C_2\,H_3$	$C_2\,H_3\,O$	$C_2\,H_3\,O,\ H\,O$
Ethyle, …….	$C_4\,H_5$	$C_4\,H_5\,O$	$C_4\,H_5\,O,\ H\,O$
Amyle, …….	$C_{10}\,H_{11}$	$C_{10}\,H_{11}\,O$	$C_{10}\,H_{11}\,O,\ H\,O$
Propyle, ……	$C_6\,H_7$	$C_6\,H_7\,O$	$C_6\,H_7\,O,\ H\,O$
Ceryle, …….	$C_{54}\,H_{55}$	$C_{54}\,H_{55}\,O$	$C_{54}\,H_{55}\,O,\ H\,O$

Various other bodies are of a similar nature, differing only in the ratio of one or more equivalents of carbide of hydrogen—$C_2\,H_2$. Each of these alcohols may be converted into an acid by the substitution of two atoms of oxygen for two of hydrogen. Thus, there can be obtained from hydrated oxide—

Of Methyle,	$C_2\,H_3\,O,\ H\,O,$	formic acid,	$C_2\,H\,O_3,\ H\,O;$
Ethyle,	$C_4\,H_5\,O,\ H\,O,$	acetic acid,	$C_4\,H_3\,O_3,\ H\,O;$
Amyle,	$C_{10}\,H_{11}\,O,\ H\,O,$	valerianic acid,	$C_{10}\,H_9\,O_3,\ H\,O;$
Propile,	$C_6\,H_7\,O,\ H\,O,$	propylic acid,	$C_6\,H_5\,O_3,\ H\,O;$
Ceryle,	$C_{54}\,H_{55}\,O,\ H\,O,$	cerotic acid,	$C_{54}\,H_{53}\,O_3,\ H\,O;$

but the contrary process has never yet been effected, for we know of no method of converting acetic acid into wine-alcohol by replacing two equivalents of oxygen by two of hydrogen, and the same remark is applicable to the alcohols related to other carbides of hydrogen.

As art can *unite* carbon with oxygen, but has no means of effecting the disunion of the two when copulated, which nature is constantly doing, so it can replace hydrogen by oxygen in the alcohols, but is, as yet, incapable of achieving the converse process, by replacing the oxygen of the acid by an equivalent of hydrogen.

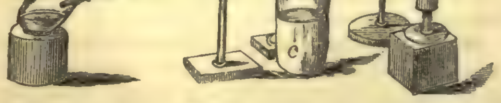
In a general and practical sense, by *alcohol* is understood the pure spirit obtained by distillation from all liquids which have suffered the vinous fermentation. It is the intoxicating principle of all vinous and spiritous liquors, as wine, brandy, whisky, *et cetera.* Distilled from wine, it bears the name—*spirit of wine.*

Alcohol is never produced except by the vinous or alcoholic fermentation of particular substances; and after the completion of such action, distillation of the fermented body affords it either in a concentrated or in a diluted state. By repeated rectifications the volatile spirit is procured, deprived of most of its accompanying water; but mere distillation, however long continued or often repeated, will not yield pure alcohol, that is, alcohol free from water—absolute alcohol. The reason is twofold: alcohol has a great affinity for water, and the distillation is insufficient to overcome this affinity; for, at the lowest temperature at which the distillate is drawn off, some aqueous vapors rise with the alcohol, and both are condensed simultaneously in the receiver; therefore, whatever the heat may be, the resulting alcohol is not anhydrous.

To procure absolute alcohol is a difficult and tedious operation: spirit of wine is to be distilled at a moderate heat from some hygrometric substance, such as anhydrous sulphate of copper, chloride of calcium, or quicklime. The best adapted for the purpose is quicklime: it is reduced to coarse powder, and put into a retort with the alcohol, and the whole mixed by agitation; the neck of the retort is then securely corked, and the mixture left for several days, during which period the water unites with the desiccating body, leaving the spirit anhydrous, and which may be distilled by the heat of a water-bath.

Fig. 35 is a convenient apparatus for this purpose. A is a glass retort; heat is applied by the lamp, C; D is the condenser, through which the tube receiving the beak of the retort passes to the flask, F. Cold water from the tank, E, enters the condenser, D, by the funnel tube, *f*, and the heated water is discharged by *b* into the vessel, *c*. The mouth of the receiver is closed by a perforated cork, to prevent the access of air, and the absorption of aqueous vapors. The dilute alcohol and coarsely-powdered desiccating compound, are introduced through the stoppered opening, *d*, the stopper replaced, and the distillation carried on at as low a temperature as possible—173° to 176° Fahr. Repeated distillations with fresh portions of lime or other hygroscopic substance are requisite, in order to free the alcohol from the last trace of water.

Fig. 35.



A singular but ingenious mode of concentrating alcohol is founded on the fact, that it does not moisten the animal tissues, but corrugates and abstracts water from them. This method was first employed by SOEMMERING to advantage. He used an ox or a calf-bladder, which was soaked for some time in water, and both freed from the fat and the attached vessels. After it is again inflated and dried, it is to be smeared over, the outside twice, and the inside four times, with a solution of isinglass, and then charged with diluted spirit, leaving a small space vacant. On exposing it to the heat of the sun in summer, or the heat of a stove, the water evaporates, while the alcohol remains. The air-bladders of fish answer the purpose equally as well as the bladders of oxen, and may, like them, be repeatedly used without injury. It is stated that, by placing the bladders filled with spirits to be concentrated over a sand-bath, with a proper degree of heat applied, absolute alcohol may be obtained in from six to twelve hours. SOEMMERING states he placed two bladders of the same size, having eight ounces of water in one and eight ounces of absolute alcohol in the other, over a sand-bath, where equal heat was communicated to both; after the lapse of four days, all the water was evaporated, and only one ounce of the alcohol.

SOEMMERING'S process, although an interesting illustration of exosmose, is not practically applicable to the production of anhydrous alcohol; it is, however, an economical method, and particularly applicable in obtaining alcohol for the preparation of varnishes. Smugglers who bring spirits into France in bladders hid about their persons, have long known that although the liquor decreased in bulk, yet it increased in strength; hence the people prefer the article conveyed clandestinely.

Treating of the above, DONOVAN says he has never been able to obtain these results to the extent specified, nor, indeed, at all. He made the experiment on alcohol of varied strengths, with small and large bladders, with thick ones and thin ones; a diminution of strength was the invariable result, unless the spirit was very weak; whenever an increase of strength did happen, it was extremely trivial.

GRAHAM has ingeniously proposed to concentrate alcohol as follows:—A large shallow basin is covered, to a small depth, with recently-burned lime, in coarse powder, and a smaller basin, containing three or four ounces of commercial alcohol, is made to rest upon the lime; the whole is placed under the low receiver of an air-pump, and the exhaustion continued till the alcohol evinces signs of ebullition. Of the mingled vapors of alcohol and water which now fill the receiver, the quicklime is capable of uniting with the aqueous only, which are, therefore, rapidly withdrawn, while the alcohol vapor is unaffected; and as water cannot remain in the alcohol as long as the superincumbent atmosphere is devoid of moisture, more aqueous vapor rises, which is likewise abstracted by the lime, and thus the process goes on till the whole of the water in the alcohol is removed. Several days are always required for this purpose, and in winter a longer time than in summer. On submitting alcohol of spec. grav. 0·827 to dehydration by this method, the following are the notes of the decreasing specific gravity after every twenty-four hours:—

When the liquid was introduced, the density was	0·827
Density after twenty-four hours' exposure to the action of the caustic lime, ...	0·817
Do. after second twenty-four hours, ...	0·808
Do. after third do.	0·802
Do. after fourth do	0·798
Do. after fifth do.	0·796

The longer time required for the concentration of the spirit in the winter season is seen from the following table, where the liquid, before enclosing it under the air-pump with the lime, had a spec. grav. 0·825:—

On determining the specific gravity after twenty-four hours, the result was	0·817
Do. after the second twenty-four hours,....	0·809
Do. after the third do.	0·804
Do. after the fourth do.	0·799
Do. after the fifth do.	0·797
Do. after the sixth do.	0·796

Quicklime possesses the property of uniting with a portion of alcohol vapor, and for this reason should not be used in great excess. **Graham** found, that when four ounces of ordinary alcohol were exposed to the action of the lime, under the bell-jar of the air-pump, one-sixth of the alcohol was lost, on account of the absorption by the quicklime. Hence the quantity of lime used should never exceed three times the weight of the alcohol, otherwise the loss of alcohol will become appreciable; the lime should be spread to as great an extent within the receiver as possible, that a larger absorbing surface may be presented to the vapor. This process could be advantageously employed in concentrating alcohol on the large scale, by taking an air-tight box, of any suitable size, provided with a number of shelves, on which powdered quicklime might be strewn, and the alcohol, contained in a number of basins, placed upon it. The apparatus might be sufficiently exhausted by a syringe, as a complete vacuum is not required. Besides these little attentions, nothing further would be requisite than to open the box at the termination of a week or ten days, and examine whether the alcohol had attained the proper density.

Alcohol may be concentrated by exposing it with lime in a close vessel, but it requires a considerably longer time; it cannot be concentrated over strong sulphuric acid, for this acid absorbs alcohol vapor with the same affinity with which it unites with water, and the heat produced is very great: a temperature of 500° to 600° Fahr. is not capable of eliminating the whole of the spirit from the mixture. Sulphuric acid diluted with water loses its property of absorbing alcohol vapor. Chloride of calcium is not well adapted for concentrating alcohol, on account of the affinity existing between these two bodies: when they are submitted to distillation, the aqueous vapor absorbed by the chloride of calcium goes over with the last portions of the alcohol; it can, however, be advantageously employed, if the process be arrested when half the quantity of spirit has accumulated in the receiver.

Drinkwater, in his investigation on the preparation of absolute alcohol and the composition of *proof spirit*, procured alcohol of the lowest specific gravity hitherto obtained. The mode of procedure was as follows:—Carbonate of potassa was exposed to a red heat, to deprive it of water, and, when sufficiently cool, was pulverized and added to ordinary alcohol, of spec. grav. ·850, at 60° Fahr., till it ceased to dissolve any more; the menstruum was then allowed to digest twenty-four hours, being frequently agitated, and the alcohol carefully separated by decantation. As much fresh-burned quicklime as was considered sufficient, when powdered, to absorb the whole of the alcohol, was introduced into a retort, and the alcohol added to it; after digesting forty-eight hours, it was slowly distilled in a water-bath at a temperature of about 180° Fahr.

The alcohol thus obtained was carefully redistilled, and its specific gravity, at 60° Fahr., was found, in two experiments, to be ·7946 and ·7947; agreeing very nearly with the determination of **Rudberg**, which has been adopted by **Gay-Lussac** and others, *videlicet*, ·7947, at 59° Fahr. With a view, however, to discover whether it was possible, by means of lime, to abstract any more water from the alcohol, the retort was again filled with fresh-burned and pulverized quicklime, and the same alcohol mixed with it; the mixture was then allowed to digest a whole week, at the ordinary temperature of the laboratory—about 60° Fahr.

After this lapse of time, the alcohol was distilled off as before, and the distillate submitted to a second operation, which was conducted very slowly at first—at the rate of about one drop in ten seconds, the heat of the water-bath being 165° Fahr. Distillation was continued till about the one-twentieth of the whole had passed over, the object being to allow any minute quantity of water which the alcohol might still retain, to evaporate or diffuse itself into the atmosphere of absolute alcohol above it; the process was then continued rapidly, the heat of the bath being increased to 180° Fahr., till about one-twentieth more had passed over; the receiver was then changed, and the latter portions slowly eliminated. The specific gravity of the alcohol, taken twice, was ·7944, at 60° Fahr. As a further test of its purity, it was divided into two equal parts; one part was again digested on quicklime, and the other on sulphate of copper deprived of water by heat, the method of operation being as follows:—

Firstly: Some lumps of freshly-burned quicklime were heated to a red heat, and quickly pulverized and introduced into the tin boiler of a small still, which was partly immersed in water, to prevent the melting of the solder. This vessel was completely filled with quicklime, and kept corked till sufficiently cool, when the alcohol was added; but it being comparatively small in quantity, the lime appeared perfectly dry: the vessel was then closely corked.

Secondly: A quantity of sulphate of copper was exposed to a red heat, to deprive it of all water; it was then very quickly ground and thrown into a small tin cucurbit, and when cold, the alcohol—insufficient to cover it—was added, and the vessel tightly corked.

These vessels, with their contents, were kept at the ordinary temperature of the laboratory for four days; they were then partially immersed in a water-bath, and kept at a temperature of about 150° Fahr., for forty-eight hours, after which the alcohol was distilled and redistilled with all the precautions before mentioned; the temperature of the water-bath, on the redistillation, never exceeded 172° Fahr., and the first tenth part was put aside in each case as possibly impure. Subjoined are the specific gravities of the alcohol thus obtained:

	Alcohol distilled from the dry cuprosulphate.	Alcohol distilled from the quicklime.
I.,	0·79470	0·79409
II.,	0·79472	0·79412

These experiments prove that anhydrous sulphate of copper is not so effective as quicklime for removing the last traces of water from alcohol. It was, however, generally observed, that the specific gravity of the alcohol gradually increased, probably from its hygrometric property, by which it absorbed a minute quantity of moisture from the air on being transferred from one bottle to another; and thinking, consequently, that a small quantity of moisture might have been abstracted from the atmosphere during the distillation—which was conducted in the usual way—and the specific gravity thus slightly increased, the operator considered it desirable to make another experiment, in which this source of error should be guarded against, by conducting the distillation, as much as possible, out of contact with the external air, and, with that view, proceeded as follows:—The different portions of alcohol before obtained were mixed together, when the specific gravity was found to be 0·7947; this alcohol was again digested at a temperature of about 150° Fahr. for fourteen days with quicklime previously heated to redness, as in the former experiment; it was then slowly distilled, out of contact with the external atmosphere, by means of a tube which passed from the condenser through a cork into the bottle in which it was to remain—the temperature at which it was distilled being 175°—and the first tenth part was put aside as possibly containing a minute quantity of water; the remainder was then distilled off at 178° to 180° Fahr. This alcohol was quickly transferred to a dry retort, and redistilled in a similar way, at a water-bath heat of 172°; the first tenth part was set aside, and the remainder kept as pure anhydrous alcohol, or as free from water as it is possible to obtain it by this process. The specific gravity was taken the next day with all the precautions before mentioned, the alcohol being also kept, during the time of transference, as much as possible out of contact with the air, when the results of four trials were as annexed:—

Temp. of room, 60° Fahr. Barometer, 29·810 inches.

I.,	·793836
II.,	·793806
III.,	·793798
IV.,	·793804
Mean,	·793811

A portion of this alcohol was subsequently digested with quicklime for three months, it was then distilled, and its specific gravity was found to be exactly the same as before. Hence one may conclude, with tolerable certainty, that 0·79381 expresses the specific gravity of absolute alcohol at 60° Fahr.

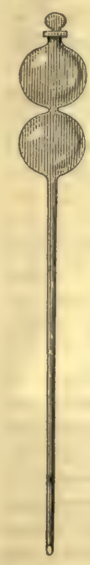
A very excellent method for the preparation of pure alcohol is recommended by Poggendorff.—Dissolve as much potassa in alcohol as it will take up, then add half its volume of water, and distil at a low temperature; a perfectly pure product is the result. On account of the high price of caustic potassa, this method cannot be applied on the large scale; but when a small quantity only is required for laboratory purposes, it is the surest way to obtain a perfectly pure product.

Properties of Alcohol.—Pure anhydrous, or absolute alcohol, is a limpid colorless liquid, of a greater fluidity than water, having a penetrating but agreeable odor, and a hot pungent taste, owing to its abstracting water from the tissue of the tongue. The great affinity of alcohol for water is the cause of its poisonous action on the system, since it destroys the vital functions of the tissues by abstracting their constitutional moisture with avidity; these violent effects are not produced when alcohol, in a diluted state, is taken in small quantities—only a pleasant hilarity follows, though larger draughts are succeeded by stupor and intoxication. It is a powerful stimulant and antiseptic. At moderate temperatures, neither atmospheric air nor oxygen gas has the slightest action upon alcohol, whether in the liquid or gaseous form; but at elevated temperatures the case is different. Alcohol, when anhydrous, burns with a whitish flame, which deposits carbon on a cold surface held in it; the flame is quite blue when it is mixed with water, and no deposit of carbon is formed. In the combustion of alcohol, very little light is emitted, but intense heat is given off: Boerhaave first showed, that when the vapor which escapes during the combustion is collected in proper vessels, it is no other than water. If alcohol be burned by a wick surrounded by a spiral of platinum wire, and the flame be suddenly extinguished, the platinum wire continues to incandesce—a phenomenon caused by the imperfect combustion of the alcoholic vapors; aldehydic acid is formed, a body possessing a pungent and disagreeable smell. Platinum black moistened with alcohol, becomes incandescent, but if much alcohol is added, so as to prevent the elevation of the temperature, oxygen is absorbed, and the alcohol is converted into aldehyde, *et cetera.* Alcohol is exceedingly volatile: if a few drops be introduced into a jar of oxygen gas, it is readily converted into vapor, and a very explosive mixture is produced. When one volume of alcoholic vapor and three of oxygen are mixed, and ignited by the electric spark, a violent explosion ensues, and two volumes of carbonic acid and three volumes of aqueous vapor are formed.

Alcohol requires an intense cold to effect its freezing. Dr. Mitchell, of Philadelphia, who, by evaporation of solid carbonic acid and ether, *in vacuo*, has produced very great cold, found that alcohol of spec. grav. 0·798 became oily and adhesive at —130°; by a greater cold it became still thicker, and at —146° it flowed like melted wax. Alcohol of spec. grav. 0·820 froze easily.

Faraday exposed alcohol to a temperature of 166° Fahr. below zero; it thickened, but did not congeal. Hence the great use of spirit thermometers when a very low temperature is required to be noted. Löwig, however, recently stated, that anhydrous alcohol congeals at a temperature of 144·5° Fahr. below zero, in opposition to the above statement of Faraday. The specific gravity of absolute alcohol is given in most chemical works as 0·7949; but from Drinkwater's experiments, before alluded to, and which were conducted with every precaution, the spec. grav. is 0·793811; it boils at 173°, at a barometric pressure of 29·5 inches. It has a powerful affinity for water; hence the necessity of keeping it in ground stoppled bottles to preserve it anhydrous. When mixed with water, much heat is produced, and a diminution in volume takes place. This is illustrated by the annexed woodcut—Fig. 36—which consists of a long tube of glass, furnished with two bulbs on the upper part, and having the elongated neck of the higher bulb closed perfectly with a ground glass stopple. The tube and lower bulb are filled with distilled water; when this is effected, alcohol is poured in till the upper bulb is filled; the stopper is next replaced, and the tube gently inverted. The two liquids now combine, and an empty space is visible, which, before combination, was completely filled. The space unoccupied shows the amount of contraction in bulk which has arisen from the combination of the alcohol and water; an elevation of temperature also takes place, in consequence of the chemical combination and the diminished specific gravity of the mixture. Thus, equal measures of alcohol, of spec. grav. 0·825, and water, each at 50° Fahr., afford, when suddenly mixed, a temperature of 70°; and a mixture of equal parts of proof spirit and water, at 50°, give, under the like circumstances, a mixture having a temperature of 60° Fahr. If alcohol and ice are mixed, the temperature is considerably lowered. Absolute alcohol, with a little more ice than it will dissolve, reduces the temperature as low as —35° Fahr. Spirit of wine, of spec. grav. 0·86, and 61° temperature, mixed with snow at 32°, is cooled down to —14° Fahr. The contraction arising from the admixture of alcohol and water, increases regularly till the liquid consists of one atom of alcohol and three atoms of water, or, by weight, of 100 parts of alcohol to 116·24 parts of water. One hundred volumes of this mixture, at 59° Fahr., is composed of 53·94 volumes of anhydrous alcohol, and 49·84 volumes of water; hence the contraction is 3·78 volumes, and the specific gravity of the mixture is 0·927 at 59°.

Fig. 36.



Thillaye shows that the mixture, when water is present in excess, or beyond a certain limit, expands sensibly; besides, his experiments prove, that when three volumes of alcohol, of spec. grav. 0·954, are mixed with seven of water, the mixed solution has a spec. grav. of 0·9850, whereas the calculated specific gravity should be 0·9863, thus indicating a decrease of gravity and a corresponding increase of volume, amounting to ·0013. This expansion, however, is only apparent, on account of the heat which is generated; but if the mixture were made of absolute alcohol and water till the specific gravity became 0·985, instead of an expansion, a contraction of 0·007 would be observed.

The following table, from the calculation of Gay-Lussac's experiments by Rudberg, shows the contraction of every decreasing five per cent. in the content of alcohol:—

Per cent., in volume, of absolute alcohol in 100 volumes of mixture at 59°.	Contraction, in per cent., of the volume of the mixture.	Per cent., in volume, of absolute alcohol in 100 volumes of mixture at 59°.	Contraction, in per cent., of the volume of the mixture.
100	0·00	50	3·74
95	1·18	45	3·64
90	1·94	40	3·44
85	2·47	35	3·14
80	2·87	30	2·72
75	3·19	25	2·24
70	3·44	20	1·72
65	3·61	15	1·20
60	3·73	10	0·72
55	3·77	5	0·31

From this table it will be observed, that the contraction is the same with mixtures containing different amounts of alcohol; for example, with the mixture containing seventy per cent. of alcohol and that containing forty per cent. the contraction is 3·44. The reason is evident: the contraction increases to a certain point, and then decreases as the proportion of absolute alcohol lessens, giving to the intermediate mixtures, between the maximum and minimum points, a corresponding degree.

The volatility of alcohol is generally affected by admixture with water, as well as its specific gravity and expansive force. Tralles found, that small quantities of water mixed with alcohol do not sensibly raise the boiling point of the liquor beyond that of pure alcohol, and Soemmering has shown that a mixture of alcohol with about three per cent. of water has greater volatility than absolute alcohol, and that a spiritous liquor compounded of ninety-four per cent. of absolute alcohol and six of water, possesses the same volatility as alcohol of 0·7947. Further, according to Soemmering, when alcohol of 0·7947 density is mixed with water till the specific gravity becomes 0·8, and distilled, those portions which first pass off are saturated with water, and the alcoholic solution in the retort becomes richer, till, in the end, absolute alcohol passes over; on the contrary, when the mixture contains over six per cent. of water, the first portions of the distillate are richest in alcohol, and afterwards they become weaker to the end of the operation—the temperature also rises as the alcohol is expelled, gradually approaching to that of boiling water, and actually attaining that point at the close of the process, when all the spirit is driven over.

Taking advantage of this property, an attempt has been made to give the strength of various mixtures of alcohol and water, by ascertaining the temperature of the vapor, for which purpose Groening has constructed the following table. It consists of three columns: the first shows the temperature; the second, the quantity of alcohol in the boiling solution; and the third, the quantity of alcohol in the vapor evolved:—

Temp.	Per cent. of alcohol in the boiling liquid in the retort.	Per cent. of alcohol in the distillate.	Temp.	Per cent. of alcohol in the boiling liquid in the retort.	Per cent. of alcohol in the distillate.
171°	92	93	189·5°	20	71
158·9	90	92	191·8	18	68
172	85	91·5	194	15	66
172·7	80	90·5	196·3	12	61
173·8	75	90	198·5	10	55
175·1	70	89	200·8	7	50
176	65	87	203	5	42
178·3	50	85	205·3	3	36
180·5	40	82	207·5	2	28
182·8	35	80	209·8	1	13
185	30	78	212	0	0
187·3	25	76			

The elastic force of alcohol-vapor is very great; the following table, showing the elastic force from 32° Fahr. to 264°, is given in the Philosophical Transactions for 1818. The specific gravity of the alcohol was 0·813.

Temp.	Force of vapor.	Temp.	Force of vapor.	Temp.	Force of vapor.
32°	0·40	135°	12·15	216°	72·20
40	0·56	140	13·90	220	78·50
45	0·70	145	15·95	225	87·50
50	0·86	150	18·00	230	94·10
55	1·00	155	20·30	232	97·10
60	1·23	160	22·60	236	103·60
65	1·49	165	25·40	238	109·90
70	1·76	170	28·30	240	111·24
75	2·10	173	30·00	244	118·20
80	2·45	178·3	33·50	247	122·10
85	2·93	180	34·73	248	126·10
90	3·40	182·3	36·40	249·7	131·40
95	3·90	185·3	39·90	250	132·30
100	4·50	190	43·20	252	138·60
105	5·20	193·3	46·60	254·3	143·70
110	6·00	196·3	50·10	258·6	151·60
115	7·10	200	53·00	260	155·20
120	8·10	206	60·10	262	162·40
125	9·25	210	65·00	264	166·10
130	10·60	214	69·30		

The expansion of alcohol by heat is not uniform; a thousand measures, spec. grav. 0·817, become one thousand and seventy-nine when heated from 50° to 170° Fahr. At a medium temperature the expansion is a little below the true mean; but with the state of dilution of the alcohol this difference between both ends of the scale becomes more marked. The greatest uniformity of expansion is between — 14° and + 98°, being about 0·00047 of its volume for every degree. The contraction of alcohol from its boiling point, 173° Fahr., has been investigated by Gay-Lussac, who gives the condensation of one thousand volumes in every 9° Fahr., or 5° C., from the boiling point of the liquid.

Temperature.		Volume of alcohol.	Temperature.		Volume of alcohol.
Centigrade.	Fahrenheit.		Centigrade.	Fahrenheit.	
74·14°	173°	1000·0	38·4°	101°	954·3
73·4	164	994·4	33·4	92	949·1
68·4	155	988·6	28·4	83	944·0
63·4	146	982·5	23·4	74	939·0
58·4	137	975·7	18·4	65	934·0
53·4	128	970·8	13·4	56	929·3
48·4	119	965·3	8·4	47	924·5
43·4	110	969·7	3·4	38	919·9

One volume of alcohol yields 488·3 volumes of vapor at 212° Fahr.; compared with water at the same temperature, the volume of alcoholic vapor is greater in the ratio of 3·14 to 1·00. The specific gravity of the vapor of absolute alcohol, taking air as unity, was found by Gay-Lussac to be 1·6133. On the assumption that it is composed of one volume of aqueous vapor and one volume of olefiant gas condensed into one volume of vapor of alcohol, the density by calculation would be 1·6070; Berzelius, however, gives the density at 1·6004. According to Despretz, the latent heat of the vapor, on being compared with that of water, is as 332 to 351.

Alcohol vapor, when transmitted through a red-hot tube, is decomposed: Saussure found that, on passing it slowly through a porcelain tube heated to redness, a little carbon was deposited on the interior of the tube, together with a volatile crystalline substance—naphthaline—and a brown empyreumatic oil; the gaseous products were carbide of hydrogen, carbonic oxide, and hydrogen. M. Berthelot passed alcohol vapor through a porcelain tube filled with pumice, and heated to redness. He obtained carbon, carbides of hydrogen, aldehyde, naphthaline, benzine, phenic acid, *et cetera.*

The analysis of alcohol by Saussure, Dumas, and others, shows that it consists of—

	Atomic weight.		Per cent.
4 Eqs. of carbon,	24	……	52·18
6 Eqs. of hydrogen,	6	……	13·04
2 Eqs. of oxygen,	16	……	34·78
	46		100·00

Formula:—$C_4 H_6 O_2 = C_4 H_5 O, H O$.

This formula of alcohol is confirmed by the composition and density of its vapor, as calculated from the density of the above constituents, *videlicet*—

	Density.
8 Volumes of carbon vapor,	3·372
12 Volumes of hydrogen vapor,	0·825
2 Volumes of oxygen vapor,	2·205
Equal four volumes of alcohol vapor,…	4) 6·402
Density of vapor of alcohol,	1·6005

Alcohol possesses the property of absorbing gases even in a higher degree than water. Considerable experiments had been instituted by Saussure on this subject, from whose results the following table has been formed:—

There is absorbed at 64·4°, of	By 1 volume air-free water.	By 1 volume air-free alcohol. sp. gr. 0·84.
	Volumes.	Volumes.
Sulphurous acid gas,	43·78	115·77
Sulphide of hydrogen,	2·53	6·06
Carbonic acid,	1·06	1·86
Nitrous oxide,	0·76	1·53
Olefiant gas,	0·155	1·27
Oxygen,	0·065	0·1625
Carbonic oxide,	0·062	0·145
Hydrogen,	0 046	0·051
Nitrogen,	0·042	0·042

About sixty-eight volumes of hydrochloric acid gas are absorbed by alcohol, as also binoxide of nitrogen, nitric oxide, and cyanogen in considerable quantities.

Most of these gases are evolved when the saturated spirit is boiled or exposed to the air, while others, such as hydrochloric acid gas, nitrous acid, *et cetera*, decompose the liquid.

Alcohol is one of the best solvents which the chemist possesses, but by dilution with water this property is much diminished. Sulphur is dissolved by it in the heat; but is deposited again in small crystals as the solution cools. An alcoholic solution of sulphur becomes turbid when diluted with water, and evolves a peculiar hepatic odor; and, like all soluble sulphides, precipitates metals from the solution of their oxides in acids, as sulphides. Phosphorus is also dissolved by alcohol, for which BUCHNER states that three hundred and twenty parts of cold, and two hundred and forty parts of hot alcohol are required. From the latter solution, one-fourth of the quantity of phosphorus deposits as it cools.

Chlorine and bromine decompose alcohol, giving rise to chloral and bromal, and hydrochloric and hydrobromic acid. Iodine is dissolved by alcohol, and forms a brown colored solution; if hot alcohol be employed, the iodine is deposited in crystals after some time, and hydriodic acid is formed in the liquid. If to a solution of iodine in alcohol, potassa-alcohol be added till the menstruum becomes colorless, iodide of potassium and *iodoform* are synchronously produced, as expressed in the subjoined equation:—

$$\underbrace{C_4 H_6 O_2}_{\text{Alcohol.}} + \underbrace{4I}_{\text{Iodine.}} + KO + O_6$$

Equal—

$$\underbrace{C_2 H I_3}_{\text{Iodoform.}} + 2CO_2 + \underbrace{KI}_{\text{Iodide of potassium.}} + 5HO.$$

By a corresponding decomposition, when distilled with hypochlorite of lime, or bleaching powder, it gives *chloroform.* Concentrated chloric, bromic, and nitric acids react violently upon alcohol, giving rise to acetic acid and a number of other bodies. This reaction is sometimes so energetic as to cause combustion. A mixture of very weak sulphuric acid and peroxide of manganese, when distilled with spirit of wine, affords principally aldehyde; acetic and formic ether are also formed, and towards the end of the distillation a weak solution, containing acetic and formic acids, passes over.

Pure chromic acid acts upon alcohol, giving rise to aldehyde and sesquiacetate of chromium. Sulphuric acid, with moderately dilute alcohol, gives rise to ether, as also do phosphoric and arsenic acids; even selenious acid, on being distilled with that liquid, causes the formation of ether. On distilling a mixture of selenious acid, sulphuric acid, and alcohol, the distillate emits a most horrible odor—hydroselenic acid—and selenium deposits in the retort. Acetic, oxalic, formic, hydrochloric, hydrobromic, and hydriodic acids, decompose alcohol, giving rise to ethers. Fluoride of borium acts upon alcohol in the heat, forming hydrofluoboric acid, boracic acid, and ether. Chloride of antimony, sesquichloride of iron, bichloride of tin, *et cetera*, decompose alcohol, forming oxides and hydrochloric ethers. Potassium behaves with alcohol as with water.

GRAHAM has shown that alcohol combines with most salts, forming with them peculiar compounds—alcoates—analogous to hydrates. A great many of the neutral salts are soluble in alcohol; in general, all deliquescent salts, excepting the carbonate of potassa, are soluble in alcohol, and those inorganic compounds which are only sparingly soluble in water, also prove insoluble in that liquid.

Alcohol is peculiarly adapted for dissolving copal, mastic, and a great number of resins which are employed in the preparation of the finest varnishes. The fats and volatile essential oils are likewise dissolved by it, and are employed with balsams in the composition of an extensive class of elixirs, tinctures, and quintessences.

Sir HUMPHREY DAVY discovered that a fine platinum wire, heated to redness, and held in the vapor of ether, continued ignited for some time. Mr. GILL has practically applied this discovery, in the formation of an alcohol lamp—lamp without flame—of the following construction. A cylindrical coil of thin platinum wire is placed, part round the cotton wick of a spirit lamp, and part above the wick, and the lamp lighted to heat the wire to redness; on the flame being extinguished, the alcoholic vapor keeps the wire red-hot for any length of time, according to the supply of the spirit, and with a very small expenditure thereof, so as to be in constant readiness to ignite tinder or a lucifer match. The proper size of the platinum wire is the hundredth part of an inch, which may be easily ascertained by coiling ten turns of the wire on a cylinder, and if they measure the tenth of an inch it will be right. A larger size only yields a dull red light, and a smaller one is difficult to use; about twelve turns of the wire will be sufficient, wrapped round any cylindrical body suited to the size of the wick of the lamp—and four or five coils should be placed on the wick, and the remainder of the wire above it.

A lamp constituted as above will require about half an ounce of alcohol to keep it in readiness for eight hours. This lamp affords sufficient luminousness to show the hour of the night by a watch, and to perform other useful services. As the Literary Journal remarks, its constantly keeping a uniform heat, and not requiring snuffing like other lamps, might make it a valuable acquisition to the chemist for experiments on a small scale, where a long continuance of a feeble heat is desirable. This suggestion may be acted upon where gas is not to be had. It would do well in Germany, where alcohol is very cheap; but the enormous price of alcohol in this country is an effectual bar to its extensive employment.

The following apposite remarks, showing the importance of having this valuable spirit exempted from duty for manufacturing purposes, the Editor deems worthy a place here. It would be impossible to name an article, says the Chemist, the duty on which is productive of so much injury to science and industry. Alcohol is the menstruum by means of which the various proximate principles of the vegetal kingdom are separated; and by which the Pharmacopolist furnishes the medical profession with those active principles on which the properties of vegetal medicines depend. On the present occasion, however, it is not the Editor's intention to dwell on this portion of the subject, but to consider those bodies which owe their origin to alcohol, commencing with chloroform.

It is calculated by manufacturers, that one gallon of alcohol, of spec. grav. ·830 to ·840, will produce two and a half pounds of chloroform—some obtain a little more. This gallon of spirit costs about seventeen shillings and sixpence, of which about ten shillings are for duty. The two and a half pounds will not sell for more than seventeen shillings—less than the cost of the spirit, and allowing nothing for the expense of hypochlorite of lime and labor. The reason that chloroform is sold in England at a lower price than the cost of its production there, is, that in Scotland the duty on alcohol is very considerably lower than in England, and that there is no duty on chloroform brought from the former country to the latter. The Scottish manufacturer is thus enabled to undersell the English in his own market.

The duty charged on alcohol amounts to about four shillings per pound on the chloroform produced from it, or nearly two-thirds of its value; the effect of this state of things is, that the manufacturer has endeavored to employ substitutes for alcohol in the manufacture; and chloroform so produced is occasionally met with in the market. Every one acquainted with the subject must admit, that chloroform, made from such a substitute as pyroxylic spirit, is less safe for employment in medical practice, and is, at any rate, far more disagreeable than that prepared from alcohol. It has been alleged, that the injurious effects that have followed the use of chloroform as an anæsthetic agent, have been traced to the fact of its having been prepared from pyroxilic spirit.

From the peculiar qualities of chloroform—its powerful solvent properties on certain gums, and the ease with which it volatilizes—there is no doubt that, if it could be produced at a moderate price, it would soon be applied to a variety of useful purposes in the arts; but, under existing circumstances, the honor and profit of such application are left to other nations, where genius is less fettered by fiscal restrictions. It is necessary to impress on the public mind, that the duty on alcohol acts as a prohibition to its use in industrial pursuits; that it would be a matter of policy in the Government to place the English manufacturer on an equality with the Scotch and the foreigner, and that the imperial coffers are not enriched by the enforcement of this tax, which inflicts such severe injury on the industrious classes. It is very true, that, in the instance of chloroform, England is supplied from Scotland; but there are many cases in which Great Britain sends to foreign countries for those articles in which alcohol performs an important part, and in which she might enjoy a considerable trade of her own.

The Chemist concludes the article as follows:—A gallon of ordinary rectified spirit produces about four pounds of commercial ether, and upon this foundation is based the extra amount of duty which is to be paid upon it when brought to England from those parts of the United Kingdom in which the duty is lower; still, it is a well-known fact, that ether may be obtained in the English market at the bare cost of the duty, namely, two shillings and sixpence per pound. There can be no doubt that, if Government does not relieve from the present duty that portion of spirit, at least, which is used for manufacturing purposes, an attempt will be made to charge upon chloroform the extra amount of duty, as in the case of ether, *et cetera*, chloroform having become an article of commercial importance.

The English manufacturer wants to be permitted to use alcohol, duty free, for manufacturing purposes; and there is no sufficient reason why he should not have this opportunity, nor why he should be compelled to seek substitutes. It cannot be expected that any manufacture in which alcohol is so important an element as in chloroform and ether, can thrive when so excessive and exorbitant a duty is charged on it. The application of these compounds to many useful purposes, is retarded or prevented by it.

ALCOHOLIC LIQUORS—WHISKY.—The subjoined historical remarks form an appropriate introduction to the manufacture of whisky:—Spiritous liquors have been noticed in some of our earliest songs and writings; and the English, shortly after the invasion, in the time of HENRY II., found the Irish people indulging in potations of this liquor. History informs us that the knowledge of *aqua vitæ* was first acquired in Europe in the reign of that monarch; but it is more than probable that the Irish were acquainted with it before the English. The strong similarity between the Irish language and the primitive languages of Asia, as stated by eminent etymologists, and the intercourse the Irish had with that quarter of the world, lead to the supposition that the art of distillation was introduced directly from India; but it is more likely that it was received from Spain or Italy, where it was early known under the epithet of *acqua vite*, or *acqua di vite*—water of the vine—as the spirit was originally extracted in those countries from the grape. The monasteries being the archives of science, and the original dispensaries of medicine, it is a natural surmise that the term *acqua vite* was there corrupted into the Latin and universal appellation, *aqua vitæ*—water of life—from its salutary and beneficial effects as a medicine; and from the Latin tongue being the general conveyancer of scientific discovery, as well as of familiar correspondence, the term *aqua vitæ* may have crept into common use to signify an indefinite distilled spirit, in contradistinction to *acqua vite*, the mere extract of the grape. The dissolution of the monasteries gave the secret of this invention to the public, and the elixir of the alembic soon attained the summit of popular regard.

CAMPION relates, that when the new settlers were attacked by any of the diseases common to the country, they used *aqua vitæ*, or *usquebaugh*, the ordinary beverage of the inhabitants, as the best restorative of health, and chief preventive of contagion. Speaking of a famine which happened in 1316, he says it was caused by the soldiers eating flesh and drinking *aqua vitæ* in Lent. It would seem that *aqua vitæ* was employed in Ireland, at one time, as opium has been amongst the Turks, to inspire heroism; and this is exemplified in the case of a knight, named SAVAGE, who lived in 1350, and, previously to entering the field of battle, ordered to each soldier a mighty draught of *aqua vitæ*. One learns from WARE and ZEDWICK, that the *aqua vitæ* or *usquebaugh* of the Irish was of a less inflammatory nature than that made in England, because the latter is supposed to be of more recent invention. Its virtues, and the directions for making it, both simple and compound, are recorded in the Red Book of OSSORY, a work compiled about five hundred years since, and which, likewise, contains a receipt for making another liquor termed *nectar*, composed of a mixture of honey and wine, having ginger, pepper, cinnamon, and other ingredients, incorporated. This mixture was called *piment*, from its pungency and spicy nature, and on account of its delicious quality it was much celebrated by the early French poets, who considered the perfuming of wine with foreign aromatics, then so dear and difficult of procuring, as the very acme of taste and ingenuity. In Ireland, it was an early practice to imitate foreign liqueurs, which, from the praise of the poets alluded to, must have even excelled those of Italy and France. *Aqua vitæ* was first used in the country as a medicine, and was considered as a panacea for all disorders; the physicians recommended it to patients indiscriminately, for preserving health, dissipating humors, strengthening the heart, curing colic, dropsy, palsy, *et cetera*, and even prolonging existence itself beyond the common limits! Hence it was eagerly sought, and the taste, thus formed, has been transmitted from generation to generation, and to which many adhere with an attachment rather strengthened than diminished by long custom.

The Latin epithet, *aqua vitæ*, the Irish term, *usquebaugh*, and the modern word, whisky, are, in point of fact, synonymous; *aqua vitæ*, signifying the *water of life*, and *usquebaugh*, which should be written *iskebaghah* or *isquebeoh*, the former implying *water of life*, and the latter *living water*. As *isqué*, or *iske*, in the Irish dialect, means water, it must appear evident that the term whisky is only a slight alteration in the pronunciation of this term. O'BRIEN and VALLENCEY both admit that *ai*, *ay*, or *ey*, are old terms for water, and *isque*, or *iske*, implying water, the compound word literally means *water of waters;* the word whisky, therefore, is of very comprehensive import, and fully expressive of this sense-subduing beverage.

It is not easy to determine the origin of the term *aqua vitæ*, as applied to exhilarating liquors, unless by an admission of the reasoning already advanced.

Having thus far entered into the history of the subject under review, the manufacturing processes will be prefaced, by an intelligent visitor, with the routine, arrangements, *et cetera*, of an extensive London distillery. He writes:—The first objects that met the eye were large granaries, or magazines, in which the grain was stored; beyond these appeared various buildings, connected with the still-room, containing a huge cylindrical worm-tub, water-tanks, and refrigerating tanks, *et cetera*. Near the entrance were the *mill* and the *brewhouse*, for conducting all those preliminary operations preceding the actual distillation. The open court presented a bustling scene—waggons bringing in yeast from the great London breweries, others laden with casks destined for different parts of the metropolis; a number of carts were conveying grain to the dairies, and at another part of the premises men were employed filling barrels with spent wash, to be sent to the fatteners of cattle and swine.

The operations of a *distillery* relate to the extraction of the alcohol from various sorts of grain. Wheat, oats, barley, rye, Indian corn, rice, and other of the *gramineæ*, whether in the raw or in the malted state, as well as the juices of fruits, sugar-cane, beet-root, potatoes, carrots, and even some of the *grasses*, and many other vegetal and natural substances, eviscerate certain elements, which, by peculiar processes, yield alcohol. Distillation is invariably one of these operations, but it is preceded by others which differ according to the nature of the ingredients employed. Those liquors universally known and abused, such as whisky, hollands, gin, brandy, rum, spirits of wine, and cordials of various kinds, all contain alcohol, which passes over in the process of distillation. British brandy, British gin, whisky, or rum, are produced from corn; French brandy, from wine; West Indian rum, from sugar or molasses. The different qualities of these various liquids depend partly on the centesimal amount of alcohol, partly on the berries, herbs, and seeds with which they are flavored, partly on their mode of manufacture, and lastly, on the substances whence they are derived. In every case, however, the substance suffering the process of distillation is a *sweet* liquid, but the means whereby the saccharine material is instituted, vary with circumstances. The extract produced from grain is converted into a kind of beer before being distilled. The fermented liquor, modified in a particular way, forms *beer* at the brewery; whilst, in the distillery, it is known under the name of *wash*, and is that liquid which undergoes, subsequently, the process of distillation.

All the grain goes through the granary, and, when required in meal, passes into the mill-room, which contains several pair of millstones, ranged in a circle, and worked by a large steam-engine. The meal next goes to the brewhouse, in which are large coppers for heating water, and prodigious mash-tuns, capable of holding many thousand gallons. Here it is mashed, and its residue sold to the cattle-feeders.

The coolers, or cooling floors, occupy the upper portion of a building adjoining the brewhouse. These floors are covered with iron plates, three or four feet square, and are joined edge to edge. Raised ledges are placed across the floors, at certain distances, to divide them into compartments; and into the shallow cells or trays thus formed, the hot wort is introduced. The whole of the immense floor, one hundred and fifty feet in length, becomes covered with a stratum of hot liquor, six inches deep, which is rapidly cooled.

From the coolers the wort descends into what are termed the *fermenting backs*, a series of square vessels of enormous proportions, where it is exposed to the action of the yeast. The alcoholic fermentation here commences, with great energy, which ceases when the sugar of the sweet wort has been transformed into alcohol; and by subsequent distillation from the large copper *wash* stills, this alcohol is obtained in a more concentrated state, forming the *singlings*, or *low wines*, of the distiller.

The system of supervision whereby the revenue in spirits is collected, is rightly, as DODD states, a remarkable instance of Excise machinery—a supervision rendered important by the great revenue yearly collected, and by the comparatively small number of distilleries from which the payments are made. The Messrs. SMITH's establishment alone pays *three hundred thousand pounds* annually to Government on the spirit manufactured; and as the duty per gallon is estimated on spirit of one particular degree of strength, the greatest caution is necessary in testing all the liquors produced, as a guarantee that every sample is charged exactly in proportion to its quantity and to its strength. There are Excise officers, as agents for the Government, almost constantly present at every distillery, day and night. They succeed each other, one or more at a time, as may be necessary, after intervals of eight hours; the periods being from six in the morning till two, thence to ten at night, thence to six the following morning. The act of Parliament to regulate distilleries was passed in 1825, and by its provisions no distiller was permitted to work till he had procured a license, which was to be renewed yearly; moreover, he was not allowed to have on his premises a still below a certain capacity. The number of stills, charges, receivers, *et cetera*, continues subject to certain restrictions; and the exact routine is given as to the mode the liquid shall run from one vessel to another in the process of distillation. The openings in the principal vessels are expressly stated; and the most scrupulous care is taken that nothing shall pass from one vessel to another without traversing a pipe having a lock or valve, which is provided and kept in repair by the distiller, to the satisfaction of the Excise officer—who has charge of the key—under a penalty of two hundred pounds. This functionary also keeps the keys to lock up the furnace doors and stills; in fact, he exercises a perfect control over every operation and process; and with the view of facilitating his superintendence, the brewing and the distilling take place at different periods, one portion of time being set apart for the preparation of the *wash*, and another for its distillation.

In order that the intentions of the law may be fully carried out, prohibiting the synchronous brewing and distilling, the buildings are detached, or conveniently divided, and the pipes, a large number of which is visible, are of various colors. The legislature requires that the conduit pipes shall be painted *black;* those for the conveyance of wash, *red;* those for the first distillate, *blue;* and those for the finished spirit, *white:* this is done in order that the officer may conveniently trace the routine of the processes; further, ladders and all other conveniences must be furnished for the easy access of the supervisor to all the vessels in the establishment.

The new act specifies that no spirit receiver shall be used in any distillery, which shall not be made, placed, and fixed, to the satisfaction of the Commissioners of Inland Revenue, and be sufficiently deep to admit of the gage being taken of the depth of fifteen inches in the centre; and every such receiver shall be so filled, that at the time of gaging the same, for the purpose of charging the duty thereon, the depth of spirit shall not be less than fifteen inches, under a penalty of fifty pounds.

The fabrication of ardent spirits is a very extensive branch of home trade. Whisky is the staple produce in this kingdom; gin, rum, *et cetera*, are made in other countries by operations analogous to those followed in the manufacture of whisky. Gin and rum are fictitiously made by several parties in this country; but they require an alcoholic liquor to operate upon, and for this purpose whisky, more or less pure, is universally used. Since whisky, then, is the principal product of the spirit manufacture of this country, preference of description will be given to it.

For its production, barley is the most abundantly employed of all the cereals, and either in the raw or malted state. Malting is a preliminary operation to which the barley is submitted by those who employ malt; but since it is not *solely* used by the distiller, the detailed description of the operations of malting will be reserved to come under BEER, as only malt is employed to yield this beverage. To show, however, the influence the malting has on the workings of the distiller, it will be necessary to notice one particular change that takes place in the constituents of the grain, namely, the metamorphosis of starch and gluten into sugar and diastase.

The change of starch into sugar is partly effected in the grain during the time it is permitted to sprout, but principally after the amylaceous and glutinous matters, or diastase, have been extracted by the water, as the latter body possesses the property of readily transmuting the remainder of the starch into sugar. The conversion of the nutritive parts of the grain here alluded to, disintegrates its natural texture in such a manner, that water will readily permeate the entire substance, and take up every particle that is of any interest to the brewer or distiller. For this reason malted grain is preferred by many distillers: firstly, because the extract is obtained more perfectly and with greater facility; and secondly, because it is supposed that the yield of spirit is larger than would be produced were the grain unmalted. But, as additional labor always involves greater expense, the cost of the malted substance is necessarily higher; besides, a Government duty is imposed upon the article, which further raises its value. To avoid, then, the expenditure which the purchase of malt exclusively would occasion, many distillers use, instead of it, a mixture of malted with raw or unmalted grain, in various proportions; and though the subsequent extraction and management of the worts from such mixtures do not offer equal facilities as when malt has been employed, yet the inconveniences are, for the most part, overcome by care and foresight; and should any slight difficulty appear, the distiller consoles himself with the assurance, that the difference in the cost of the original material will fully compensate any of the minor casualties.

By guarding against the difficulties to be encountered, when a mixture of raw and malted grain is operated upon, as will be pointed out in the succeeding pages, the yield of spirit will be as large as if malt was wholly taken; a fact proved by CLEMENT and others who have investigated the subject, and also by several intelligent manufacturers.

Whether malt is exclusively used, or a mixture, the substance must be either ground or crushed, in order to destroy the adhesiveness of the valuable principle of the grain, and to expose an extensive surface to the solvent action of the water in the preparation of the extract. As said before, the malting effects the disintegration to a considerable extent; hence the reason why malt is not required to be in a very minute state of division when subjecting it to the action of solvents. On the contrary, mixtures, into the composition of which large quantities of raw grain enter, must be finely ground, for the cause just assigned.

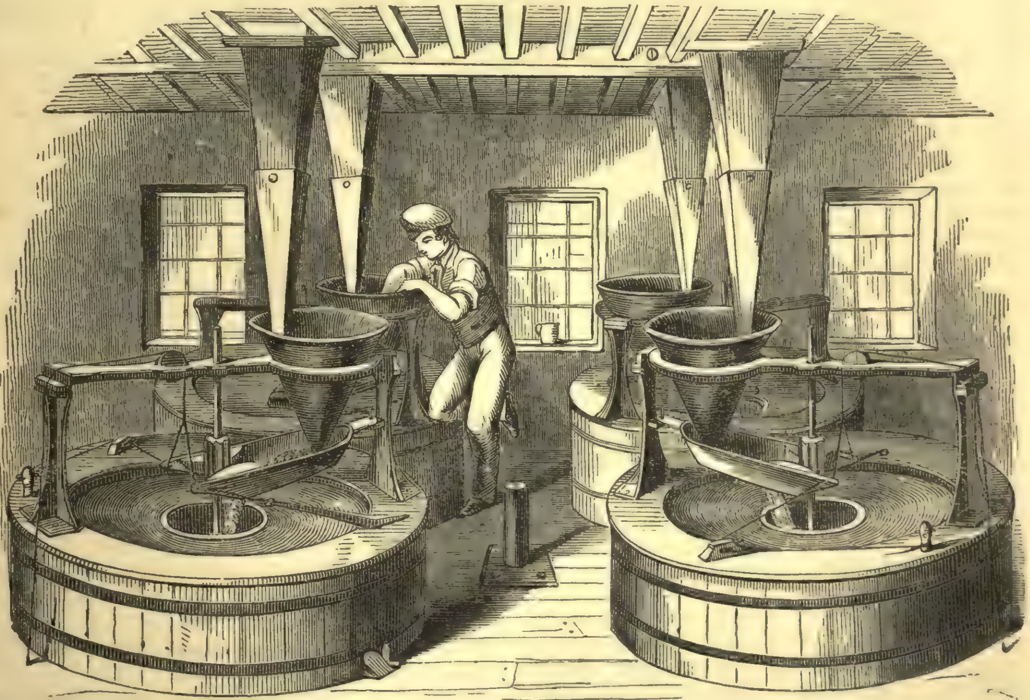
Ground or crushed malt always yields a wort that is comparatively clear; mixtures, on the other hand, never give a bright wort, but dense solutions, on account of the large quantities of starch and plastic matter which are carried off mechanically in the water.

This behavior of the malt and mixtures, constitutes one of the principal differences between the brewer's and distiller's mode of making the worts; the former must have a clear extract, as the liquid, after being submitted to the slow fermentation, remains to give *body* to his beverage. Such an extract cannot be otherwise obtained than by using malt entirely. It is optional with the distiller whether he uses malt or mixtures to prepare his worts, as he can run the starchy liquor into the fermenting tun, there to undergo the alcoholic fermentation, partly by catalysis, or the action of contact, and partly by the preliminary alteration of the starch, owing to the activity of the fermentation, into sugar before the alcohol is formed.

In other respects, the operations of the brewer and of the distiller are closely allied, excepting, that the distiller's object is to urge fermentation to its utmost, and finally, to separate by distillation the spirit thus formed from the wash, after which the residuary liquor is accounted of little value; but the brewer's aim is to prevent the fermentation going beyond a certain point, and the alcohol produced is left in conjunction with the wash.

Considerable attention is required of both parties, and especially of the distiller who employs raw grain, in preparing the worts, owing to the tendency of the matter *to set*, which prevents him from extracting the valuable portions. The main point, however, in the distiller's business, demanding particular care, is the proper management of the fermentative action succeeding the making of the worts, to insure the conversion of the whole of the saccharine matter into alcohol: he must also guard against the acetous fermentation, and various other difficulties, which, if overlooked, would be extremely detrimental.

Fig. 37.

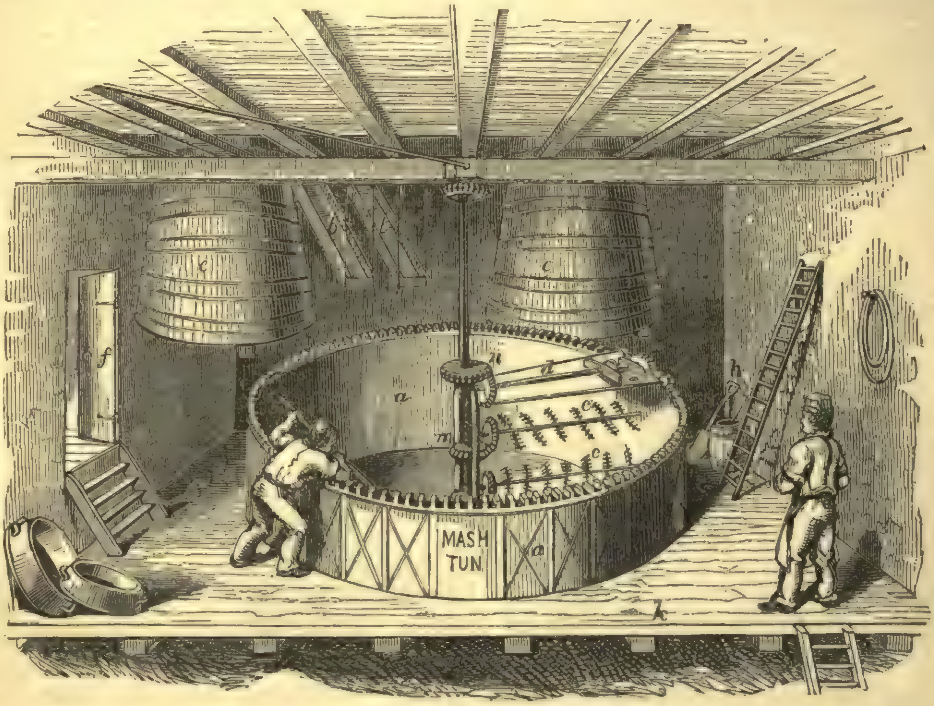


The several stages in the manufacture will now be fully treated of under the heads—GRINDING, MASHING, FERMENTING, and DISTILLING.

GRINDING.—The granary is a large building of brick or stone, having three spacious stories, on which the malt or raw grain is hoarded. One of the granary floors is appropriated to the kiln-dried barley, which lies spread in a stratum five feet thick, ready to be conveyed to the mill. When it is to be ground into meal, the grain is taken to a room immediately over the mill-chamber, and discharged through trap-doors into cloth sleeves, which conduct it to the hoppers. In the mill-room several pair of stones are seen ranged in a circle, and are set in motion by a shaft from the steam-engine. Fig. 37 shows the nature of the operations. These stones grind all the raw grain; while the malt is passed through a crushing-mill, consisting of two rollers placed nearly in contact. In the lower room is a vertical cylindrical partition, enclosing the mechanism whereby the millstones are rotated in the room above, and around it are pipes or openings for conducting the meal from the grinders into sacks fastened to them. The meal, as it issues from these pipes, has a temperature of about 100° Fahr., from the mechanical friction of the stones.

MASHING.—The mash tun is the most important vessel employed in this department. It is made of cast-iron plates, firmly bolted together, and circular in shape. Fig. 38 represents the mash tun at a large Scotch distillery: *a a* is the mash tun, twenty-eight feet in diameter, and eight feet deep. From the middle of the tun rises a vertical shaft, *m*, set in motion by machinery, and thus revolving the mechanism, *d c c*. This apparatus, by rotating horizontally and vertically, effectually rummages the whole liquor in the tun: *d* is a rod extending from the pillar, *m*, to the edge of the tun, round which its outer extremity is carried on a toothed wheel, gearing into the teeth round the tun; it is driven by the bevel wheels, *n*. Connected with this rod, *d*, are two parallel rods, *c c*, which it carries round with it; to these rods are fixed bent cross bars or feathers, which also revolve in consequence of the double motion of the rods, *c c*, rotating on their axes at the same time that they turn round the shaft in the centre of the tun. In their action they much resemble the paddles of a steamer, mashing and churning the menstruum. The one rod is exactly over the other; the paddles attached to the lowest, pass within two inches of the bottom. When the tun is only half filled, the lower rod, *per se*, mashes the contents. *k* is a platform, so that the men may have easy access to the tun; *f* is a door leading to the mill, where the grain is ground into grist; *b b*, two channels or sluices, for conducting the grist from the granary into the mash tun; *e e*, wash-backs, resting on rafters, *et cetera*, which project from the wall. The wash-backs are used for containing the weak worts drawn from the last two *sperges*, or mashings of the grist, after the principal extracts have been drawn off; they are pumped up into *e e*, and kept to macerate fresh grist in the next operation; *h*, the entrance to the long rooms, in which are twenty or thirty fermenting tuns. Several large copper vessels, besides the tuns, are in use, for the purpose of heating the water for mashing the grist; they hold several thousand gallons, and are heated by a furnace.

Fig. 38.



Having described the mash tun, the operations and materials employed for the preparation of the worts will be now considered.

It has already been stated that the grist may be barley meal, oats, or malt in variable proportions, according to circumstances. Large quantities of oats, on being mixed with the grist, confer a peculiar flavor, which is easily recognized by those who have experience in the taste of spirit. When barley malt and raw barley meal form the grist, one part of malt to two or three parts of the raw ground grain are considered the best proportions, though one part of malt to five, six, eight, nine, or even fifteen parts of the raw grain are often used. When oats are employed, the best proportion is three parts of barley malt to one of oats; but satisfactory results are obtained when the malt and oats are used in the ratio of two of the former to one of the latter. If the proportion of raw grain be large when compared with that of the malt, it is a general custom to add a quantity of chaff, in order that, when the mashing water has extracted the saccharine and starchy portions, it may be more easily filtered or drawn off.

The quantity of malt and grain used at each mashing, depends on the size of the distillery; hence no fixed rule can be laid down. In the distilleries in Dublin, the quantity of grist at each brewing varies with circumstances, from eight hundred bushels, the lowest, to two thousand bushels, the largest quantity. In nearly all cases, it is composed of seven eighth-parts of raw or unmalted, and one eighth-part of malted grain.

Previous to introducing the malt, a quantity of water, at a temperature between 140° and 150° Fahr., is run into the mash tun, and the ground malt and meal are then added. A number of workmen, with stout wooden spatulas or oars, keeps the mixture in brisk agitation, until the grist is thoroughly moistened, and neither clots nor lumps remain. In the larger establishments, this part of the operation is effected by machinery, and is much more efficiently performed than by manual labor. The perforated false bottom allows the wort to percolate into the space between it and the true bottom of the tun, from which it is drawn off more easily into the under-backs,—large vessels placed beneath the mash tun, wherein the worts are collected till pumped into the cooling-backs. Distillers and brewers are more variable in their mode of working than any class of manufacturers who carry on business extensively. In no one operation do they seemingly follow a common rule, each having some favorite plan of a supposed greater merit than others; hence the difficulty of giving a true and comprehensive detail of these branches. This assertion has been partly demonstrated already, when speaking of the grist; and in the next operation, the mashing, it becomes more manifest.

The whole of the saccharine and fermentable matters of the grist introduced into the mash tun, is generally extracted in three, always in four mashings at most; but the manner of doing so is different, according to the notions of the manager. At one time, the first, second, and third mashings were evaporated till the mixture acquired a density of about 1·05, when it was ready for the fermenting tun, the fourth wash being reserved for extracting fresh quantities of grist. Some employ the water in the first and second extract in such quantities as that the wort will be of a strength fit for fermenting, and the third and fourth wash may be concentrated by evaporation to the proper density, and then added to the preceding; or these dilute solutions may be made of the proper strength by running them on fresh quantities of ground malt and grain. Others, again, manage the quantity of water in such a manner that the product of the first extract will have the density necessary for submitting it to the fermenting vessels. The remaining three washings are rendered stronger either by evaporation, or mashing with fresh portions of malt or grist. In the latter case, the quantity of water is larger in the first mashing than in the preceding instance, where the first two extracts are made of the strength 1·050, which together amount to about twice the volume of grist

In MACFARLANE and Co.'s distillery at Glasgow, two hundred and sixty hundred-weight of grist, including a sixth or a fourth of malt, are taken for an ordinary mash, and these are put into the mash tun, and about seven hundred and eighty-eight barrels of water—nearly twenty-eight thousand three hundred and sixty-eight gallons—are poured upon them at two stages of the operation.

In the Dublin distilleries, about seven-eighths of raw grain are employed. Like the preceding, the first mash is the only one let into the fermenting tun, the succeeding small worts being kept for the next day's brewing; and in preparing this wort about five barrels of water are taken to the quarter of grist, but more if small worts are used; to completely exhaust the grist, about the same amount of water is required for the subsequent mashing.

The temperature of the water varies with the quantity of malt present; when the malt and raw grain are mixed in the proportion of one of malt to two of grain, the first mashing may be made at a temperature of 150° to 160° Fahr., but if the malt and grain be as one to four, six, or nine, then the water should not exceed 145° for the first mashing, in order to prevent the *setting* of the mass. A longer time is likewise required for the first mashing with a large quantity of raw grain than if it were entirely malt, as the starchy matter of the grain is more difficultly extracted than the saccharine principle which replaces it in the malted grain. From one hour and a half to two hours generally suffice for this operation, where the contents of the mash tub are kept in agitation by machinery, and the proper heat of the water has been attended to; but very often the time occupied may extend to three or more hours.

In successful cases, the time required for the wort to clarify, is about one to two hours. As the temperature of the solution becomes lower from contact with the grist, and from the agitation, it is customary not to add the whole of the water employed in the first mash at once, but to retain from half to a quarter of the liquid, which is added, at short intervals, towards the middle of the operation. This serves to keep the heat more uniform, and the work is more effectually accomplished.

In the Scotch distillery above mentioned, when the first water at 140° permeates the whole of the grist, the remainder of the seven hundred and eighty-eight barrels is poured in, at a temperature ranging between 175° and 180°, so as to heat the whole contents of the tun to 150°.

After the wort has been drawn off into the under-back, and pumped into the coolers, the second *sperge* is then let in upon the grist remaining in the mash tun, and a similar treatment to the foregoing given to the mash; the time occupied is one hour and a half, and the density of the weak wort is from fifteen to sixteen pounds per barrel.

Since the greater part of the saccharine and starchy matters of the grist is extracted in the first affusion, there is but little danger of the setting of the mash in the second washing, so the water is of a higher temperature than that employed in the first case, generally 180° Fahr.

After this wort has been let into the under-back, the third and last sperge is made, and in about an hour and a half the wort is drawn off; its density is from three to five pounds per barrel. Both these mashings are pumped into wash-backs, and are let down to form the first mashings in the next day's brewing, and thus the work succeeds by *three* sperges or waterings of the grist; the first being drawn off at the proper density for fermentation, while the remaining two are retained to be further strengthened by additional extractive matter.

On tasting the solution during the *infusion* of the first wort, a very peculiar difference is observed. At first nothing particularly striking is apparent, but in a very short time the solution begins to acquire a sweetish taste, which becomes more perceptible till in the end the liquor possesses the lusciousness of malt worts. Hence it is evident, that the starchy matter of the grist, as it is extracted, is resolved into glucose, or grape sugar. Two causes serve to effect this change: the first and chief agent is the peculiar body *diastase*, which is generated in the malt during the germination of the grain. This body possesses the property of converting much more starchy matter into sugar than is present in the malt. It reacts on the starch of the raw grain, and produces the same action as if the grain itself was malted. The gluten of the grain is capable of producing the same change, but it requires a considerably longer time than the active body in malt. When only one part of malted barley is used to five of the ground raw grain, the excess of the vegetal principle, diastase, is sufficient to effect the ready transformation; but when nine parts of the raw material are used to one of malt, the quantity of the active principle in the malt is inadequate to saccharify the whole of the starch, and a portion is consequently left to the slower action of the gluten: this accounts for the longer time and greater trouble which the wort takes in preparing for the still when a large quantity of the raw grain is proportioned to the malt. When a wort is being made, considerable time elapses before the starch is wholly transformed into sugar, and in the ordinary period allowed by the distillers in the fabrication of the worts, this conversion is never complete, a large portion of starchy matter remaining unaffected. Thus, if it be attempted to make a wort of two hundred pounds of saccharine matter per barrel in the ordinary way, the process fails, in consequence of the starchy matters assuming a jelly-like appearance long before the above strength is attained. In order to obtain the strongest wort possible from raw grain, the extract, diluted, should be left to repose for a longer period, during which the gluten reacts like the diastase of the malted grain, and when the whole of the starchy matter becomes soluble, the solution is drawn off and concentrated by evaporation at a low temperature.

The specific gravity of the first wash is generally about 1·050; the second wash has a specific gravity of about 1·010 to 1·015; the third, 1·008; and the fourth is little higher than water. The strongest wort procurable from grist, containing over four parts of unmalted grain, is obtained by evaporating the first mashing. The strength, even by this treatment, never exceeds one hundred and fifty pounds of saccharine matter per barrel, while the wort of malt, treated similarly, may be obtained of two hundred pounds to the barrel.

In consequence of restrictions once imposed upon the distiller by the Excise, he was precluded from attempting to manage the worts by any decided improvement in method or principle, and had to submit to the dictates of a Board, whose judgment in such matters was often inferior to his own. When these regulations were first drawn up, the Scotch distillers were compelled to produce, from one hundred gallons of wort, nineteen gallons of spirits, of one-to-ten over hydrometer proof, or of a specific gravity equal to 0·90917. At a later period, the quantity of spirits was reduced to fourteen gallons, and, still later, to thirteen gallons, from the hundred gallons of wort. The strength of the wort was regulated at this period, and specified at seventy pounds of saccharine matter per barrel. The English distillers were exempted from these changes in the regulations, so that they continued, as usual, to make their worts of whatever strength they thought proper to yield the nineteen gallons of one-to-ten over proof.

On the supposition that the whole weight indicated by the saccharometer had been decomposable matter, capable of yielding alcohol in the fermenting tun, thirteen gallons of the forementioned strength would be produced according to theoretical calculations; but this is never obtained in practice, for, from repeated experiments, conducted on a large scale with every requisite care, it has been found that not less than fifteen pounds of saccharine matter remain undecomposed, so that only fifty-five pounds of the seventy prescribed by the Excise regulation came into active operation. When the quantity of spirits was nineteen gallons to the hundred gallons of wort, it was made of the requisite strength by producing a concentrated extract of saccharine matter from malt, raw grain, *et cætera*, and adding it to the wort till the proper density was obtained.

From the supposition that this infusion was made up of sugar, treacle, and other similar articles, the parliament prohibited its addition to the wort in the Scotch distilleries; and its strength was limited to seventy pounds of saccharine matter per barrel, in order to prevent the secreting of the excess of spirits which a strong wort would yield above the standard quantity—thirteen gallons.

It has been said that a wort of sixty-two pounds per barrel, which would yield twelve per cent. of spirit of one-to-ten strength, or 0·90917 spec. grav., is preferable to the proportion adopted by the Excise. The original Dutch hollands are obtained from a wort considerably weaker than the above, and it is generally admitted that the Dutch spirits are superior to the Scotch.

The whisky made by smugglers in Scotland was long preferred by the inhabitants, and was purchased at a higher price, under the name of Highland whisky. This was partly owing to its being made entirely from malt; but the chief reason was, that, from the unfavorable circumstances under which they operated, their wort was necessarily much weaker than the wort of the legal distillers, and, on an average, was not much stronger, probably, than the wort of the Dutch hollands.

For a long period, the illicit production of spirits in the highlands of Scotland was a great source of annoyance to the Excise, and of trouble to the parties illegally distilling, to such an extent that several of them had been ruined thereby. The public, too, helped to maintain this contraband trade, for the smuggled goods were, generally, preferred to those of the legal distiller, on account of the improved taste and bouquet which the former were supposed to possess. While this feeling remained, it was impossible to put an end to the production of smuggled whisky in Scotland. To overcome the preference of the inhabitants for the highland spirit, Government removed the restrictions which bound the manufacturers, so far, that they were able to distil from malt at almost the same rate as they before did from grain. Hence the high reputation of smuggled whisky has gradually fallen off, and the business of those engaged in it has almost discontinued.

The chief reason, it is asserted, that influenced the Government to retain the limitation under which the distillers were placed, was to insure the payment of the duty on the spirit actually distilled; yet it was a matter which required elucidation, how the duty could be levied with greater accuracy though all the restrictions on the strength of the wort were removed. Experiments have pointed out, that in the best-conducted distilleries not more than four-fifths of the saccharine extract in the wort undergo the alcoholic fermentation, and that, for every pound of such extract that suffers decomposition by the fermentative process, half a pound of alcohol, spec. grav. 0·825, is produced; since a gallon of the spirits, one-to-ten over proof, or spec. grav. 0·90917, contains four and three-fifth pounds of alcohol of spec. grav. 0·825, from which it is evident, that for the production of a gallon of spirits of 0.90917, the decomposition of nine and one-fifth pounds of sugar are required; but as only four-fifths of the quantity of sugar present suffers the alcoholic fermentation, eleven and a half pounds will be required in the wort for production of the above quantity of spirits. The regulation of the Excise laws might be based upon these facts, and the duty levied on the wort proportionably to the quantity of saccharine matter, allowing eleven and a half pounds for every gallon of spirits.

At present the distiller can bring his wort to any degree of strength he may think proper or advantageous; but he must give a written notice of this to the Excise officer in attendance four hours before running the wort into the fermenting tun, or he will incur a penalty. The duty imposed is regulated by the strength of the worts, and the subsequent gravities and measurements which are repeatedly taken.

In the employment of malt, the proportion, in moderate-sized factories, stated by **URE**, is five hundred bushels, coarsely ground. This quantity is introduced into the mash tun, which is of a size proportionate to this supply of malt, and nine thousand gallons of water, at a temperature of 160° Fahr., are run in upon it. The whole is kept in brisk agitation, by machinery, for an hour, then allowed to rest, and, after the grains have subsided, about six thousand gallons of wort are drawn off into the coolers. From four thousand five hundred to five thousand gallons of water, at 180° Fahr., are run in upon the residuary grains in the tun, and the mashing continued for about three quarters of an hour; the mixture is then allowed to rest, and the weak worts drawn off. A third treatment of the grain, with the same amount of water as the preceding, takes place, in order to take up all the soluble matters of the grain; and when this has been drawn off, and the grains have been drained of all the solution, both the second and third mashings are mixed, which constitute nine thousand gallons; the mixture is employed next day, at a temperature of 160°, to mash five hundred bushels of fresh malt, and is drawn off into the coolers, when it has become saturated with saccharine matter, as before shown, and the residuary grain subjected to the same operation as the grains of the preceding day.

Sometimes rye is used instead of malt. Ninety bushels of it are mixed with one hundred and ninety bushels of raw grain, thus constituting two hundred and eighty bushels in the whole, for the mashing of which five thousand two hundred gallons of water are required. The temperature of this water, as is pointed out in the beginning of the remarks on this part of the subject, should not be so high as when all malt has been used, and as was also stated above, the time allowed for mashing is greater; the subsequent washings are reserved for exhausting fresh portions of grist.

THE COOLING.—Wort of grain has a much greater tendency to form acetic and saccharic acids than the malt worts. Saccharic acid contains the same number of equivalents of carbon as sugar, and seems to be produced from sugar in the same way that the acetic acid is from alcohol.

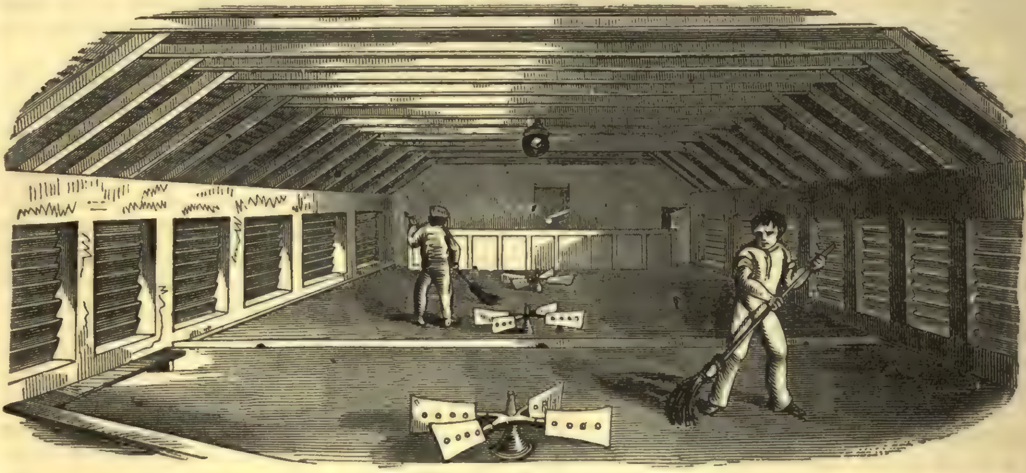
Seven atoms of anhydrous sugar contain the elements of one equivalent of saccharic acid, three equivalents of melassic acid, and seventeen equivalents of water; and this is at once shown by the annexed formulæ:—

$$\begin{array}{c} \text{Seven equivalents of sugar,} \\ \text{equal } C_{84}\,H_{63}\,O_{63}. \end{array} \left\{ \begin{array}{lr} \text{1 Saccharic acid,} \,.\,. & C_{12}\,H_{10}\,O_{16} \\ \text{3 Melassic acid,} \;.\,. & C_{72}\,H_{36}\,O_{30} \\ \text{17 Water,} \,\ldots\ldots\ldots & H_{17}\,O_{17} \\ \hline & C_{84}\,H_{63}\,O_{63} \end{array} \right.$$

On account of the liability to acetification above alluded to, it becomes the important business of the distiller to oppose it, which is done by bringing the solution as speedily as possible to that temperature at which the fermentation proceeds. Various methods are pursued by different distillers, according to the extent of the factory.

In several of the factories the coolers are shallow rectangular vessels, into which the first wort is pumped as soon as it has passed the under-back, to the depth of two, three, four, or more inches. The coolers in Messrs. MACFARLANE's distillery are two in number, each being one hundred and twenty-four feet in length, by thirty-two in breadth, and nearly a foot deep. Fig. 39 represents one of these coolers. They are placed at the upper part of the building, one over the other, and are open on all sides to the winds. Over each cooler is fixed three *flighters*, or machines like horizontal windmills, which, as they are made to revolve rapidly by means of an engine, sweep a powerful air-current over the worts, producing also a circular current in the liquid, which makes it traverse the coolers equally. As the wort is introduced into these coolers, it stands at 135° to 140° Fahr., and is cooled here to 70° or 80°, the temperature at which it stands when run into the fermenting tuns; this cooling is effected in about five hours in the winter-time, but requires eight or nine hours in the summer season.

Fig. 39.



An improved method of cooling the wort has lately been followed, *videlicet*, by conveying the hot liquid through a course of tin piping placed in a stream of cold water. By this means, and the use of the proper extent of piping, the wort may be cooled down to the temperature of the surrounding water, or any other intermediate degree that may prove most advantageous. Worts cooled down by this means lose none of the water by evaporation, as they otherwise would do if cooled in the flat shallow wooden coolers, and consequently, with the exception of the little alteration in gravity the difference of temperature occasions, the worts remain of the same density that they indicated when drawn from the under-back.

FERMENTATION is the most important stage through which the materials in the hands of the distiller have to pass, and one which not only demands considerable skill and attention for its proper management, but also requires extensive knowledge, both of the principles of chemistry, and of practical results. Indeed, the success of the operation almost entirely depends on the fermentation of the wort; and, unless governed with due care and dexterity, a failure will be the consequence. If the distiller possesses superior knowledge, and is acquainted with scientific data, a favorable field for practice is offered to him, to bring those acquirements to bear upon this part of his business. The proper fermentation of worts oftentimes baffles the most skilful, the process being so changeable in its nature. Formerly, the Scotch distillers used to add three and a half per cent. of fresh yeast, or four to four and a half, and sometimes five per cent. by measure of stale yeast, to the wort in the fermenting tun. The whole of the yeast was not added at once, but in two, three, four, or more quantities. Usually one and a quarter to one and a half per cent. of yeast was added the first day, and the remainder on the second and third days; though some managed by introducing the whole of the remaining yeast, after the first addition, on the third day, and, if requisite, a further quantity to complete the fermentation. Fresh yeast, if it could be obtained, was taken at first, and the succeeding quantity put in might be stale yeast; in which case a larger measure was employed than if the ferment were fresh.

The large amount of yeast formerly employed was in consequence of the great density of the worts. Distillers now generally use from one to one and a half per cent. of fresh yeast, very rarely two per cent. Of this about three-fourths per cent. are added when the wort is let into the tun, and the remainder after the second day—sometimes when the attenuation reaches 1·030 or 1·035. The quantity subsequently added may be stale yeast, taking, however, a little excess over the usual allowance of the fresh ferment.

This yeast is invariably obtained from the large London porter breweries, the quantity produced in the provincial ones being insufficient. The portion of yeast which is thrown off the porter during its fermentation, is the best; but often that sold is the slimy dregs which remain in the bottom of casks when the clear porter is racked off. A great deal of the success of the fermentation depends upon the goodness of the yeast, and the quantity used is regulated by its freshness.

In the course of fermentation, the liquid incalesces about 20° Fahr. above its ordinary temperature. DONOVAN gives the following as a fair statement of the specific gravity and temperature of the wort of a five days' fermentation, the original specific gravity being 1·050 :—

First morning,	temp., 70° ;	spec. grav.	of wort,	1·050
" evening, ..	70°	..	..	1·050
Second morning, ..	72°	..	..	1·046
" evening, ..	76°	..	..	1·032
Third morning, ..	80°	..	..	1 022
" evening, ..	84°	..	..	1·012
Fourth morning, ..	88°	..	..	1·007
" evening, ..	88°	..	..	1·005
Fifth morning, ..	88°	..	..	1·003
" evening, ..	86°	..	..	1·001

The time occupied by the fermentation varies, extending over a period of between three and six days, and, on some occasions, seven or nine days. Difference of season has a great influence on the celerity or slowness of the fermentation. During the first few days the tuns are exposed as much as possible to the atmosphere, and after this time they are covered over tightly to exclude the air. Two reasons have been alleged for this arrangement: first, to prevent the escape of the carbonic acid, which, it is supposed, forwards the action; and, secondly, if suffered to diffuse itself into the atmosphere, it would carry off portions of the alcohol. For the first supposition, some explanation may be offered. It seems that the carbonic acid, when confined, causes the greater attenuation of the liquid. It is known that the carbonic acid from fermenting tuns, when conducted through fresh worts, causes fermentation; but this is not so complete as when yeast is added. It may, however, happen, that a portion of the active principle of the ferment is carried over mechanically, and that by this the fermentation is caused, it being doubtful whether carbonic acid generated from any other source would have the same effect. With regard to the second reason, it is scarcely admissible, as the fermentation is nearly terminated before shutting down the tuns.

Distillers never take yeast from the fermenting tuns, but beat it into the liquid, being of opinion that any such abstraction would render the fermentation less complete, and consequently diminish the proportion of spirit.

The best temperature for the wort, when let into the fermenting tuns, is about 70° to 75° Fahr. in winter, but often it stands about 57°; during the fermentation the temperature rises 20° or 25° Fahr., being at the maximum elevation between 82° and 90°. When the heat of the liquid, at the commencement of the fermentation, is about 70°, the acquired caloric will be apt to raise the liquid to a degree which is favorable to its acetification; hence great care must be exercised to prevent the temperature exceeding 95°.

Difference in the time of the fermentation of worts is nearly always observed, owing to the variation of the quality of the yeast. As the fermentation proceeds, the specific gravity of the wort diminishes, in consequence of the decomposition of the saccharine matter into carbonic acid and alcohol, which is expressed by the distillers as *attenuation*, and is the standard by which they judge of the success of the operation. The amount of spirit which the wash or wort will yield, may be known from the determination of the specific gravity, or degree of attenuation, which has taken place.

Two reasons may be offered for the diminished specific gravity after fermentation.

1. The disappearance of the saccharine matter in the fluid, which, were it not for other fixed bodies present, would lower the density to that of distilled water. The whole of the sugar, however, is not decomposed, and, consequently, the specific gravity of the fermented wort, apart from the consideration of the alcohol generated, would be proportionally greater than the water in its ordinary state, as the quantity of undecomposed matter is more or less.

2. The results of the fermentation are carbonic acid, which escapes, and alcohol, which remains; the alcohol, having a less specific gravity than water, diminishes the density of the latter. The aim of the distiller is to have the attenuation of the wort to correspond with water, which may be readily done, provided his yeast is tolerably good, and that his worts are dilute. When this object is gained, it does not, however, follow, as many of them suppose, that the whole of the saccharine matter has been decomposed. The weight of a volume of alcohol being much less than that of a corresponding volume of water, it is evident, if both be comminuted, that the resulting liquid will have a specific gravity less than the latter; and to make up the strength, so as to equal the density of water, a greater or less amount of saccharine matter is requisite, or, in other words, a quantity of saccharine matter remains undecomposed, which raises the density considerably higher than that of water at ordinary temperatures. Generally, this quantity of undecomposed sugar increases with the original strength of the worts, as the alcohol generated in the proportionate bulk of those extracts is larger; and with it the decomposition of the saccharine matter is partially arrested, in consequence of the property which alcohol has of preventing eremacausis, or fermentation. This fact is easily proved by adding some alcohol to a portion of the wort in active fermentation, so that the liquid will indicate a specific gravity equal to, or a little below water; the action of the ferment is arrested, and the sugar, necessarily, remains in the liquid intact. If the solution be introduced into a retort, or small common copper still, and about one-third of the liquid drawn off at the temperature of the water-bath, the spent wash in the still run once more into a vessel, and a little yeast added, active decomposition of the sugar sets in, and a corresponding quantity of alcohol and carbonic acid is produced. The case is similar in the fermentation on a large scale: and the annexed table, which is taken from the Encyclopedia Britannica, shows this in a clear manner. The density of the nine worts examined ranged about 1·045, and the degrees of attenuation to which they were reduced were as follows :—

1.	Specific gravity after attenuation......	1·0012
2.	" "	1·0045
3.	" "	1·0018
4.	" "	1·0000
5.	" "	1·0012
6.	" "	1·0045
7.	" "	1·0047
8.	" "	1·0007
9.	" "	1 0007

Upon examining the wash after the termination of the fermenting action, it was found that 4·34 parts of the sugar had been decomposed, and that one part remained intact; thus showing, that when worts are even purposely diluted, nearly a fifth part of the saccharine matter will escape decomposition; and, where worts are much stronger, or more concentrated, of course the loss will be much greater. On the large scale, the attenuation cannot often be carried below 1·0012. Some rare instances may occur, in which the specific gravity may be reduced to 1·000, or even 0·998; but in these instances, the worts must be in a proper state of dilution, and the ferment, or yeast, of the first quality.

Ure mentions the works of a Scotch distiller, where the wash, when let into the tun, had a specific gravity of 1·065 to 1·060. The contents of the fermenting tun are stated at three thousand gallons of wash, and the temperature, at the time of its introduction, 64° to 74° Fahr. Two gallons per cent. of barm were added, and the liquid agitated. When the attenuation had reached 1·04, another gallon per cent. of barm was added. He further remarks, that if the fermenting tuns are small, the temperature of the worts should be higher than when the reverse is the case. Fermentation is known to proceed favorably when the bubbles of carbonic acid mount in rapid succession. Should the fermentation flag, it is almost a hopeless task to restore vigorous action. Some try the addition of *bubs*—wort brought into a rapid state of fermentation in a tub by a large proportion of yeast—but this plan is seldom successful; besides, the law prohibits the addition of any wort after the expiration of twenty-four hours from the time the fermenting tun is charged, and if it be known that after that time any has been added, the distiller incurs a penalty.

With concentrated worts the fermentation goes on briskly for a short time, and then, after the alcohol has accumulated, the fermentation lags, and no further addition of yeast will revive it. **Donovan** found that the saccharine matter in such fermented worts possessed a highly disagreeable taste and smell. Hence the necessity of having the worts properly diluted, to avoid too great a waste of saccharine matter; yet the worts must not be too dilute, for then the fermentation will sooner cease, and the diluted alcohol will be more apt to run into the acetous fermentation. The attenuation is urged no longer than the time that the head of yeast falls, the distiller thinking it more advantageous to overlook the matter remaining undecomposed, than risk the loss which he would expose himself to from the formation of vinegar. Indeed, unless immediate distillation of the fermented wort is resorted to, a heavy loss is often incurred from this source, and more so if the alcoholic liquor be exposed to the air for any considerable time. This is noticed by the increasing specific gravity of the worts, and the peculiar aroma of acetic acid. It is, however, easily guarded against; generally, distillation is resorted to; but if atmospheric air be excluded from the fermented liquor, no injury is sustained. For this purpose the tuns are rendered air-tight by means of a well-fitting cover, through which a large tube passes, and enters the bottom of an open tub placed over the fermenting tun, which, in this instance, is filled quite full; the barm and froth rising are forced through the pipe into the open tub, and when the fermentation slackens, these matters return into the tun. Many distillers use butter to keep the wash from overflowing the tun. In general, the fermenting tuns are conical vessels of larger capacity than is required to hold the wash when first introduced, which serves the double purpose of containing the froth, and preventing the escape of the heat generated during the process.

At present, in the larger distilleries, the fermenting tuns are of iron, and have an outer casing of wood. These are found to be much more easily managed than the wooden ones, the iron having a greater conducting power. Should the heat of the wort get too high, cold water is introduced into the space between the envelope and tun; and if it be too cold, it is readily brought to the proper temperature by supplying hot water.

As a good attenuation is the great desideratum, to the attainment of which the distiller's attention is particularly directed, it may be advisable, before closing this part of the subject, to enter more fully into its nature, and inquire into the causes which affect it, alluding, at the same time, to the alcoholic fermentation.

Fermentation may be regarded as the putrefaction of a substance void of nitrogen. A change of properties is produced in the substances fermented, arising from new combinations of their principles. Sugar, for example, is converted into alcohol and carbonic acid, by the process of alcoholic or vinous fermentation. This process, viewed under its simplest conditions, consists in adding a certain quantity of yeast, or other ferment, to an aqueous solution of sugar. Carbonic acid shortly begins to be eliminated, and the alcohol, simultaneously produced, unites with the water.

In addition to the alcohol and carbonic acid formed by the decomposition of the juice, there is also produced a yellow or grey insoluble substance, containing a large quantity of nitrogen. It is this body which possesses the power of inducing fermentation in a new solution of sugar, and which has, in consequence, received the name of ferment.

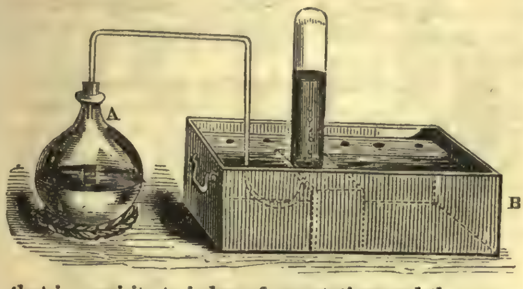
Yeast from beer, and that from wine, examined under the microscope, present the same form and general appearance. They are both acted on in the same manner by alkalies and by acids, and possess the power of inducing fermentation anew in a solution of sugar: in short, they are considered identical. The alcohol and carbonic acid are produced from the elements of the sugar, and the ferment from those nitrogenized constituents of the juice, termed gluten, or vegetal albumen.

The fermentation of pure sugar in contact with yeast, is evidently a very different process from the fermentation of wort, or of *must*—the liquid expressed from grapes when fully ripe.

In the former case, the yeast disappears during the decomposition of sugar; but in the latter, a transformation of gluten is effected simultaneously, by which ferment is generated. Thus yeast is destroyed in the one case, but is formed in the other.

The experiment may be most conveniently exhibited and conducted upon a small scale in an apparatus like the annexed—Fig. 40. The syrup and yeast are introduced into the bottle, A, from which a bent tube issues, passing under the inverted jar placed in the water-trough, B. It will now be found, that all that is requisite to induce fermentation, and the consequent production of alcohol from the above materials, is to subject them to a due temperature—say between 70° and 80°; they then soon begin to act upon each other, and the principal points to be noticed are—

Fig. 40.



Firstly, that carbonic acid is evolved;
Secondly, that the sugar slowly disappears;
Thirdly, that alcohol is gradually formed.

It will be further observed, that the contact of air, or oxygen, is unnecessary. It is, indeed, in many instances injurious.

As respects the quantitative results of this experiment, it has been ascertained by DUBRUNFAUT, BOULLAY, and DUMAS, that by commencing with cane sugar, it is, in the first instance, converted into glucose, or grape sugar, and that the grape sugar is then resolved into carbonic acid and alcohol.

Now, grape sugar, which, in its ordinary hydrated or crystalline state, is $C_{12}\,H_{14}\,O_{14}$, loses, when carefully dried at a little above 212°, two atoms of water, and becomes $C_{12}\,H_{12}\,O_{12}$; and assuming such to be its composition, one atom of the anhydrous grape sugar would be resolved exactly into four atoms of carbonic acid and two atoms of alcohol; or, in other words, one hundred and eighty parts of the dry grape sugar would yield eighty-eight parts of carbonic acid, and ninety-two of alcohol; the results of experiment confirm this theoretical deduction:

$$\text{1 atom of dry grape sugar, } C_{12}\,H_{12}\,O_{12} = \left\{\begin{array}{l} \text{4 atoms of carbonic acid, } C_4 \quad O_8 \\ \text{2 atoms of alcohol,} \ldots\ldots C_8\,H_{12}\,O_4 \\ \hline \text{1 atom of sugar,} \ldots\ldots\ldots C_{12}\,H_{12}\,O_{12} \end{array}\right.$$

If the starting point be cane sugar $C_{12}\,H_{11}\,O_{11}$, it yields somewhat more than its weight of carbonic acid and alcohol, inasmuch as it, in the first instance, assumes an atom of water to form grape sugar; but if, on the other hand, common grape sugar $C_{12}\,H_{14}\,O_{14}$ be taken, it affords less than its weight of carbonic acid and alcohol, because it contains two atoms of water in excess. Hence it is seen that one hundred and seventy-one parts of cane sugar, produce one hundred and eighty parts of carbonic acid and alcohol, while one hundred and ninety-eight parts of common grape sugar give the same results. It is also found that a very small quantity of yeast is required to excite the fermentation of grape sugar or glucose, whereas cane sugar requires a much larger proportion.

In the production of beer and wine, and in the case of the fermentation of a solution of sugar, as just described, the results, as relate to the production of alcohol, are the same; the sugar is decomposed in consequence of the presence of a ferment. When yeast is used, its particles are seen to become covered with small bubbles of carbonic acid, which cause them to rise to the surface of the liquor, where they discharge them, and as they again sink, they gradually acquire a fresh coating of bubbles, which they carry up as before; in this way, that intestine motion of the whole menstruum is produced, so characteristic of active fermentation. The process is also attended by a considerable elevation of temperature, and when complete, the liquor clarifies, the yeast precipitates, the sugar has disappeared, and in its stead is found alcohol. A trace of ammonia also makes its appearance.

These extraordinary changes can only be induced by the action of yeast, or some analogous ferment. Its *modus operandi* has been the subject of much experiment and discussion, and involves some very curious considerations.

MITSCHERLICH has proved that actual contact of the particles of the yeast with the dissolved sugar is essential. He suspended a wide glass tube, the bottom of which was made of bibulous paper, in a jar of a solution of sugar, the tube being itself filled with the same solution. Some yeast was then put into the syrup contained in the tube, where it soon induced fermentation, and the alcohol there formed passed through the pervious bottom, and, together with carbonic acid, diffused itself in the surrounding liquor; but the real phenomena of fermentation, namely, the destruction of the sugar and the formation of alcohol and of carbonic acid, were limited to the syrup in the tube containing the ferment, and the sugar in the outer vessel remained unchanged. Yeast which has been deprived of all matter soluble in water, still retains its power of exciting fermentation. The active part of yeast, or barm, is composed of minute vesicles, containing globules, and these germinate in the saccharine liquor, and produce a microscopic plant.

Few productions have created more interest, or excited greater discussion among chemical philosophers, than yeast, and its nature and mode of operation have been the source of many an anxious and keen inquiry. These points are now, however, to a very great extent set at rest; its fungoid character is generally admitted, and its action in inducing fermentation pretty well understood.

In one part, however, the history of the yeast plant is still incomplete, and this relates to its development. Most observers admit that the yeast fungus, in the different forms of yeast in use, is in an incomplete state of development, and many, influenced by this conviction, have made attempts to discover the plant in its perfect condition. Such was the motive which induced TURPIN, in the ardour of scientific zeal, to spend a whole night in a brewery, in order to trace out the successive steps in the germination of the yeast plant; and although he has stated that he made out distinctly that the cells of sporules became multiplied by budding, and that they adhered in couples, and even in rows, according to the time which had elapsed after the commencement of the germination, yet, as will be presently seen, he failed to discover the fungus in its perfect form. Animated with the like desire of discovering the true development of this curious production, **Pereira** bestowed much time and attention in its examination. He examined yeast at Messrs. **Hanbury** and **Buxton's** brewery in London, at various stages of the fermentation of both porter and ale, from a few hours to many. In the more advanced stages of fermentation, he observed that globules of yeast were frequently in strings or rows, apparently forming moniliform, often branched plants; but as the cells were very readily separable, he could not satisfy himself that the adhesion was otherwise than mechanical, such as is observed in the blood-discs, when they arrange themselves in series like money-rolls, and such as we sometimes perceive even in organic amorphous precipitates. His experience agrees with **Schlossberger**, who states that he never could perceive a budding or bursting of the yeast cells, accompanied by a discharge of their contents, nor could he ever produce this by compression.

These curious brachial and other adjustments of the cells of yeast to each other, appeared to be the work of chance; it is, however, proper to add, that the artificial rupture of the cells has been effected by **Mitscherlich**, who also confirms **Turpin's** observation of the budding of the yeast cells.

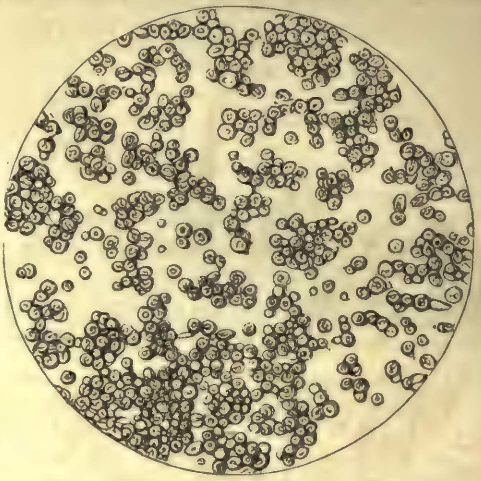
M. **Robin**, after describing the development of the sporules by budding, remarks:—Only this mode of propagation of the vegetal is known: its fructification in the air has not been seen, nor can it be seen, because it perishes at the part at which it is in contact with the atmosphere, so that it cannot yet be classed amongst the fungi which fructify only in the air, nor even among the algæ, from which it is separated by very many particulars, and which bear fruit under the water.

Dr. **Hassall**, another zealot in the same cause, performed many diligent examinations of the yeast plant, and succeeded in tracing it through all the stages of its growth to its perfection. He classes the growth into distinct stages, as follows:—

First stage, or that of *sporules*.—In this, the ordinary state in which the yeast plant is met with, it consists entirely of sporules; these are for the most part separate, but sometimes feebly united in twos, threes, and even in greater numbers; they vary in size and form, some are several times smaller than others, and nearly all contain one or two nuclei, which are the germs of future sporules. Fig. 41 represents the yeast fungus in the first stage of its growth.

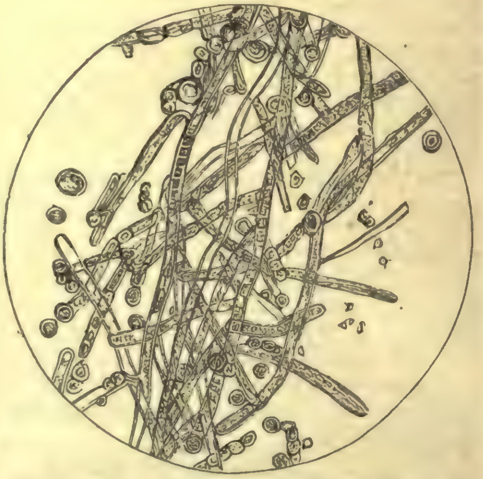
Second stage, or that of *thallus*.—After the lapse of some days, and under favorable circumstances, the sporules become much elongated; a division or a partition appears in each, on which account it is formed into two distinct cells; the extension still continuing, other septa appear, until at length, jointed threads—at first simple and undivided, and afterwards jointed—are formed, and the plant now exists in the form of root-like threads, or thallus. The yeast plant, in the state of thallus, constitutes *Mycoderma cerevisiæ* of **Desmagieres**. See Fig. 42.

Fig. 41.



Third stage, or that of *aerial fructification*.—After the lapse of a further time, vertical threads spring up from the thallus, Fig. 43; these, when the plant has reached its complete development, become branched, each branch bearing, at its extremity, a row of rounded and beaded corpuscles, which are about the size of the sporules, but differ from those bodies in their darker color and firmer texture. Occasionally, in the rows of beaded corpuscles, one cell several times larger than the rest is seen.

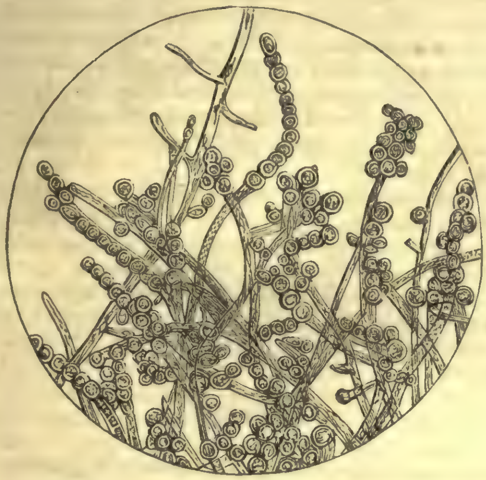
Fig. 42.



Such is a brief description of the development of the yeast plant in its several stages.

From a consideration of the structure of the sporules of the yeast plant, their evident fungoidal character their rapid growth, *et cetera*, **Hassall** concludes that the reason why the true or aerial reproduction had never been discovered, was to be found in the fact, that the yeast being used always in the state of sporules, sufficient time was not allowed to it, under ordinary circumstances, to attain its full development, for which purpose, probably, many days would be required. To prove the validity of this inference, he placed, in an eight ounce bottle, a table-spoonful of malt, poured over this about four ounces of hot water, and partially closing the mouth with a perforated cork, set it aside for a fortnight. At this time he found that the aerial production had taken place, which other observers failed to detect. Hence the German algologist, KURTZING, is in error, in regarding it as a confervoid production.

Fig. 43.



The plant, it appears, grows at the expense of the sugar, giving out carbonic acid, and leaving alcohol. The active part of yeast remaining after it has been well washed with water, consists of—

	Mitscherlich.
Carbon,	47·00
Hydrogen,	6·60
Oxygen,	35·80
Nitrogen,	10·00
Sulphur,	0·60
	100·00

It also contains a trace of phosphorus, and of fixed bases. Of this yeast, from two to three parts are required for the decomposition of one hundred parts of sugar; and if there be an excess of sugar, it remains unaltered after the fermentation.

That portion of the yeast which remains in the form of a deposit, after fermentation is over, is inefficient as a ferment. It appears, when examined under the microscope, to consist of the ruptured cells, and is unsusceptible of vegetation; so that, during the fermentation of sugar, a certain portion of the yeast plant dies, and is decomposed, the living plant being required to sustain the fermentative process. If more yeast be present than is required for the decomposition of a certain quantity of sugar, the deposit which is in that case formed consists partly of broken and partly of entire cells, and the latter retain their power of inducing fermentation. It would further appear, that the portion of the yeast which has become inert as a ferment, has lost the greater part, if not the whole, of its nitrogen; and certainly, one of the results of the changes which ensue during saccharine fermentation, appears to be the formation of ammonia, which, though so small in quantity as generally to elude observation, may be detected amongst the gaseous products.

For the formation of yeast or ferment, the requisites appear to be, the presence of sugar and of a nitrogenized principle in aqueous solution, and the contact of air. A solution of pure sugar undergoes no change, but the addition to it of any proteiniferous compound, with the access of air, induces fungous vegetation, and, with it, fermentation. Grape sugar, and some form of protein, are present in all sweet fruits, and their juices are accordingly susceptible of fermentation, although, as GAY-LUSSAC's experiments have shown, they also require the presence of oxygen. Grape juice carefully preserved from the contact of air, as when expressed in an atmosphere of hydrogen, or of carbonic acid, may be kept for months without change; yet, upon the admission of a few bubbles of air, or of oxygen, it presently begins to ferment, and when the process has once commenced, it continues. It has, however, been shown by SCHWANN, that a fermentable liquor, namely, one containing sugar and a nitrogenized principle, undergoes no change when the air which has access to it has been previously passed through a red-hot tube; URE and HELMHOLTZ have repeated the experiments with similar results. Hence it has been assumed that the germs or seeds of the fungi are present in the atmosphere, and only await the requisite conditions and food for their vegetation, which they find in saccharine and other liquors; and that the vitality of these germs is destroyed by a certain elevation of temperature. Yet in GAY-LUSSAC's experiments, a few bubbles of pure oxygen gas—in which, from the mode of its preparation, organic germs could not be supposed to exist—induced fermentation; and he further states, that on decomposing a portion of must excluded from air, by the voltaic current, fermentation ensued, apparently in consequence of the evolved oxygen; but HELMHOLTZ could not obtain this result.

According to MITSCHERLICH, animalcules are also concerned in the phenomena of fermentation. Thus, if a little sugar be added to a liquor containing *infusoria*, the animalcules increase rapidly, and ferment is at the same time formed; on adding more sugar the multiplication of the animalcules ceases, but there is an increase in the production of the ferment.

FOWNES remarks,—It often becomes a matter of great practical importance to have it in our power to excite the vinous fermentation, under circumstances in which ordinary yeast cannot be obtained. In making bread, for example, although the use of yeast may be avoided by employing what is called leaven, or dough which has already become sour, and partly putrefied by spontaneous change—a practice which has been followed from the most remote antiquity, and is still occasionally in use—the bread so made is always to be distinguished by a peculiar sour and nauseous taste and smell, and can never bear comparison with that fermented by yeast. According to the above-cited chemist, yeast of the most unexceptionable quality can be artificially produced at will.

Berzelius states, that although the reproduction, as it were, of yeast—the conversion of a small into a large quantity—is a very easy thing, yet to produce that substance from the beginning is very difficult. He describes a process for this purpose, on the authority of Dr. **Henry**, and which consists in taking a strong infusion of malt, saturating it with carbonic acid, and then exposing it for some days to the proper fermenting temperature; when a small quantity of yeast is gradually formed and deposited, which may, by various contrivances, be made to give origin to a larger. Presently, the behavior of a malt infusion when left to itself, at a temperature of 70° or 80° Fahr., for some time, will be considered, from which it will be seen that the addition of carbonic acid is wholly unnecessary. Diastase, for instance, according to its peculiar condition, whether fresh from the germinated grain, slightly putrefied, or in a still more advanced state of that change, possesses the singular power, in the first case, of changing starch into dextrin, and ultimately into grape sugar; in the second, of causing the conversion of sugar into lactic acid; and in the third and last, of exciting the vinous fermentation.

Now, if common wheaten flour be mixed with water to a thick paste, and exposed, slightly covered, to spontaneous change in a moderately warm place, it will be observed to run through a series of metamorphoses which seem very closely to resemble those in the case of diastase.

About the third day of such exposure it begins to emit a little gas, and to exhale an exceedingly disagreeable sour odor, much like that of stale milk. After the lapse of some time this smell disappears, or changes in character, the gas evolved is greatly increased, and is accompanied by a very distinct and somewhat agreeable vinous odor; this will happen about the sixth or seventh day, and the substance is then in a state to excite the alcoholic fermentation.

A quantity of brewer's wort is next to be prepared in the usual manner, by boiling extract of malt with hops, and, when cooled to 90° or 100°, the decomposed dough before described, after being thoroughly mixed with a little tepid water, is added to it, and the temperature kept up by placing the vessel in a warm situation; after the lapse of a few hours, active fermentation commences, abundance of carbonic acid, having its usual agreeable pungent smell, is disengaged, and when the action is complete and the liquid clear, a large quantity of excellent yeast is found at the bottom, well adapted for all purposes to which that substance is applied.

In one experiment the following materials were used: A small handful of ordinary wheat flour was made into thick paste with cold water, covered with paper, and left seven days on the mantel-shelf of a room where a fire was kept all day, being occasionally stirred. At the end of that period three quarts of malt were mashed with about two gallons of water, the infusion boiled with the proper quantity of hops, and, when sufficiently cooled, the ferment added. The results of the experiment were, a quantity of beer—not very strong, it is true, but quite free from any unpleasant taste—and at least a pint of thick barm, which proved perfectly good for making bread. When the yeast alone is the object to which attention is directed, the hops may be omitted.

A moderately strong infusion of malt which has not been boiled, when suffered to stand in a warm place for some days, speedily becomes sour and turbid, and begins to evolve gas; this change rapidly progresses, carbonic acid is given out plentifully, and a deposit of thick, insoluble, whitish matter formed, which readily excites fermentation in a dilute solution of sugar: the supernatant liquid contains alcohol and traces of acetic acid.

When wort which has been boiled and hopped is set aside to decompose spontaneously, the change it undergoes appears to depend very much upon its strength: if weak, three or four days elapse before any action is noticed; a scum then collects upon the surface, and a brown flocculent substance precipitates, which is incapable of exciting fermentation in a solution of sugar, while the liquid gives off a flat offensive smell. Should the infusion experimented on be stronger, then the action is different; the liquid becomes turbid from the separation of a yellowish adhesive substance, a good deal of gas is very slowly emitted, alcohol is formed, and the deposit at the bottom of the vessel proves a pretty active ferment to sugar. The acidity of the liquid is trifling, and its smell is somewhat disagreeable. These differences in the behavior of boiled wort may also depend upon the quantity of hops added, which act as an antacid, and upon the length of time during which the ebullition had been continued.

The effect produced in a spontaneously fermentable liquid by vegetal acids, or acid salts, such as cream of tartar, is a curious subject of inquiry. From an experiment made upon some wort, it appeared that the result of such addition tends to the formation of lactic acid. We know that when the juices of grapes, currants, and gooseberries, are exposed to the air, the vinous fermentation commences apparently at once; whereas, in an unboiled infusion of malt, which is destitute of these substances, lactic acid seems to be first formed, although ultimately the two fermentations proceed collaterally. It has been stated, when speaking of the spontaneous decomposition of wheaten dough, that an acid state preceded that in which it became an alcoholic ferment; if, in this condition, it be mixed with a dilute solution of common sugar, and the whole be kept warm for several days, it furnishes a sour liquid which is rich in lactic acid, and which gives with zinc a white crystallized lactate of this metal. There is a tendency in the liquid to run into the alcoholic fermentation, and to produce vinegar by a subsequent change; but still the quantity of lactic acid so formed is very considerable.

Common wheat-gluten, then, in its mode of decomposition strikingly resembles diastase; like that substance it runs through two different dynamic conditions. It is successively a lactic acid and an alcohol ferment. Is it too much to expect that it might, by proper means, be detected in a third condition, namely, as a sugar ferment, like diastase itself in the state in which it exists in malt? Is it not possible that diastase, as a definite proximate principle, has no more existence than yeast; that its powers are purely dynamic, and that it is, in short, nothing more than the gluten of the seed in one of its earliest stages of decomposition? This is an interesting inquiry, but its prosecution will be somewhat difficult, owing to the rapidity with which these changes follow each other. It must be remembered that no one has yet succeeded in getting diastase in a state fit for analysis. Having several times alluded to this substance, the Editor appends the following particulars with regard to it.

PAYEN and PERSOZ were the first to obtain diastase from barley malt. It may be procured from brewers' malt, but in greater quantity from germinated barley, carefully prepared for the purpose, in which the germ has been allowed to attain about the length of the seed. The malt is pulverized, and macerated in, or triturated for a few minutes with water, at the temperature of 70° or 80°. The pasty mixture is then strongly pressed, and the turbid liquor, which runs from it, filtered: the filtrate is then heated in a water-bath to about 170°, at which temperature the greater part of the foreign nitrogenized matter coagulates, and may be separated by filtration; the clear filtrate retains the diastase, and may be used for many purposes. Other bodies besides the diastase are also contained in the liquor, but they may, to a great extent, be separated by the addition of anhydrous alcohol, which forms a flocculent precipitate of diastase insoluble in that liquid. It should be collected and carefully dried at a low temperature; for, when heated in a moist state above 190°, its properties are materially altered. It may be further purified by a second solution in water, and precipitation by alcohol; if the solutions are brown, animal charcoal will decolor them.

Diastase may also be obtained without the aid of heat, but the process requires caution. The operation consists in triturating the finely-ground malt as before with a little water, pressing out the liquor, and carefully adding a little alcohol, so as to coagulate its albuminous contents without precipitating the diastase; the solution is then filtered, and the diastase separated by the further addition of strong alcohol. It may be purified by a second aqueous solution and alcoholic precipitation, and should be dried at a temperature not exceeding 100°, or in vacuo over sulphuric acid. Diastase is white, soluble in water and in dilute alcohol, but insoluble in strong alcohol. Its aqueous solution is tasteless, and soon becomes sour and decomposed. Its effect upon starch is entirely destroyed by boiling. It contains nitrogen; its ultimate composition, however, has not been accurately determined.

Although diastase thus prepared cannot be regarded as a perfectly pure substance, it nevertheless possesses a remarkable power of converting starch into dextrin and glucose—to such an extent, indeed, that one part of it is capable of modifying two thousand parts of starch.

The conversion of starch into glucose is slow; but its transformation into dextrin takes place rapidly, and becomes at once perceptible. If the reader will introduce a tepid infusion of malt—diastase—into a vessel filled with starch paste, the temperature of which is kept, as nearly as possible, at 160°, he will find that in a few minutes the change becomes manifest by the liquefaction of the mass. Now, if portions of the liquid be tested from time to time with iodine solution, which produces a blue coloration as long as any starch is present, it will be found that the intensity of the hue is quickly diminished, and that soon a point is reached when the complete cessation of any tinge indicates the total transmutation of the starch into dextrin; the transition of the latter into glucose is not accomplished under several hours. The mode in which diastase operates upon the starch is not known. We are at present only cognizant of the fact; but this fact is of great importance in a practical as well as a theoretical point of view. As science progresses, these recondite processes will have more light thrown upon them.

DISTILLATION.—The chief object of importance in this stage is the still; and no other article of manufacturing apparatus has undergone so much alteration. Whatever form or construction may be given to it, the philosophy of distilling rests upon the different degrees of volatility of the bodies subjected to the operation. By attention to this principle, several bodies of varied densities may be separated, if suitable means are adopted. It was known to the earliest alchemists that the more volatile a body, the less heat is required to convert it into vapor; and *vice versâ*, the temperature at which that body is liquefied is lower than what is required to effect the resolution of a liquid which boils at a higher temperature. By transmitting the vapor of these liquids simultaneously through a good condensing medium, the temperature of which is lower than the boiling point of the heavier, but not so low as the point at which the lighter boils, it becomes evident that the vapor of the heavier liquid will be condensed, while the other loses nothing of its acquired expansion. This is beautifully illustrated by the subject under consideration. The temperature at which water boils is universally known to be 212°; alcohol boils at 176° Fahr. If a mixture of these two liquids be introduced into a retort or still, the mixture will boil at an intermediate temperature, proportionate to the quantity of each liquid present; but the alcohol being the lighter is driven over in larger quantity at first, carrying with it some aqueous vapor: as the boiling continues more water is given off, until, at the end of the operation, nothing passes over but steam. When the mixed vapors are conducted through a tube placed in water below 212°, and not so low as the boiling point of the mixed liquid, the water is condensed, and the alcoholic vapor remains unaffected, till the temperature of the refrigerator is lower than 176°. The same thing happens in distillation with the ordinary apparatus. In the first and second volutions of the worm in the condensing tube, the aqueous portion is more or less condensed, and the spirit retains its acquired elasticity, till it traverses the worm to where the temperature is below its boiling point; then it becomes liquid. It was a great desideratum in the days of the early distillers to obtain a concentrated spirit, as at those times only the common still and worm were in operation, and the whole of the water eliminated with the alcoholic vapors was found in the receiver. By repeated distillations of the first products, a pretty concentrated spirit could be obtained; but this was effected at a loss of time, fuel, and alcohol.

To arrest the formation of acetic acid, as soon as the attenuation of the wort has reached its lowest point it is run into the still with as little delay as possible. According to the old methods, the wash is distilled in two large retorts or stills, each of about six to twelve hundred gallons capacity, suited to the size of the factory. The retorts are provided with a rotatory chain apparatus for preventing the lies from adhering to the bottom of the still, which, unless prevented, would deposit and become charred from the heat, and communicate a disagreeable taste to the spirit.

Previous to distillation, about one pound of soap is added to every hundred gallons of the wash. When the charge of wash is eight thousand gallons, the distillation is carried on as speedily as possible, without risk of it *running foul* till about two thousand four hundred gallons are drawn off. These constitute the *low wines*, or singlings, and are very weak, not averaging above 63° below proof on Dicas' hydrometer. The remainder of the spiritous product of the eight thousand gallons is received in another vessel for a further distillation. The singlings are redistilled, or *doubled*, in the second still, and the spirit drawn off till it begins to acquire a disagreeable taste and smell—these are what constitute the *faints*, and owe their peculiarity to an essential oil which is held in solution. The faints are collected in the faints-back, and mixed with the muddy part of the first distillation, water is added, and the whole redistilled. Very weak singlings are obtained, which, upon a second distillation, afford finished spirit.

Some distillers continue the first distillation as long as any alcohol comes over, and then subject the low wines to a second distillation in the spirit still. The first portions are more or less blue or muddy, and consequently are run into the faints-back. As soon as the spirit becomes clear, and devoid of a disagreeable odor, it is run into the spirit-back. The quantity of the spirit obtained in well-regulated distilleries, amounts to about three-fourths or even four-fifths of the low wines operated upon; faints are drawn over at the end of the distillation, and are turned into the faints-back, together with the first portions. These faints are mixed, as before stated, with a considerable quantity of water, and distilled, in order to free them from the disagreeable oil eviscerated by the husks of the grain.

A self-regulating bath is, in some distilleries, put in the capital of the still. The common Scotch stills have the capital fifteen to twenty feet high, to prevent the wash from boiling over into the worm; it is customary to strike the capital from time to time with a rod, and from the sound emitted, it is inferred whether it be empty, partially filled, or in danger of an overflow; in the latter case the fire is withdrawn, or damped by means of a spout near the furnace-door, and which is supplied with water from a cistern in the upper part of the building. When a very pure spirit is required, it is customary to dilute the liquor with water and submit it to a third distillation, in order that the distillate may not have the harsh taste of strong alcoholic liquids. In the improved stills, a liquid sixty per cent. over proof is obtained, even in the first distillation, and at a considerable saving of fuel, time, and labor, while the use of soap, *et cetera*, is unnecessary.

The usual yield of proof spirit from malt is between two and two and a half gallons per bushel. The largest amount of spirit procured from one quarter of corn is twenty gallons. As a general rule, the lower the heat at which the distillation is carried on, the purer will be the spirit. When an excess of soap has been used, and the distillation urged too rapidly, the distillate often possesses a saponaceous flavor, which is occasioned by its fatty particles being carried over mechanically in the vapor, and dissolved in the alcoholic liquid. The manner in which the soap acts to prevent the charge running foul, is as follows:—During fermentation, and subsequent transference of the wort into the still, small portions of acetic acid are generated, which decompose part of the soap, setting free the oily compound which rises to the surface of the liquor, and breaks the bubbles of vapor as they ascend through it from the bottom of the retort; hence the liquid cannot pass over unless the boiling be violently urged.

The average quantity of spirit obtained by the Irish distillers from a barrel of malt—twelve stones—is eight and a half gallons, Irish measure, or six gallons five pints and one and a half noggins, imperial measure, of twenty-four per cent. over proof by Dicas' scale.—*Donovan.*

Dr. URE performed several experiments, at the request of the Board of Excise, for the purpose of deciding a discussion which had taken place in Ireland, relative to the extent to which raw grain could be fermented; the most decisive of his results is the following: Three bushels of mixed grains were taken, consisting of two of barley, one-half of oats, and one-half of malt, which, being coarsely ground by a handmill, were mashed in a new tun with twenty-four gallons of water at 155°. The mash liquor drawn off amounted to eighteen gallons, at the density of 1·0465; temperature of 82° Fahr. Being set in a new tun, it began to ferment in the course of twelve hours, and in four days it was attenuated down to gravity 1·012. This yielded, upon distillation, in low wines, 3·22 gallons, and by rectification, in spirits, 3·05, while the quantity equivalent to the attenuation by the tables was 3·31; being an excellent accordance in such circumstances.

The inquisitorial system imposed by law upon our distilleries might lead a stranger to imagine that our legislators were desirous of repressing, by every species of annoyance, the fabrication of the fiery liquid which infuriates and demoralizes the lower population of these islands. But, alas! credit can be given them for no such moral or philanthropic motive. The necessity of the Exchequer to raise a great revenue, created by the wasteful expenditure of the state, on the one hand, and the efforts of fraudulent ingenuity, on the other, to evade the payment of the high duties imposed, are the true origin of that system.—*Ure.*

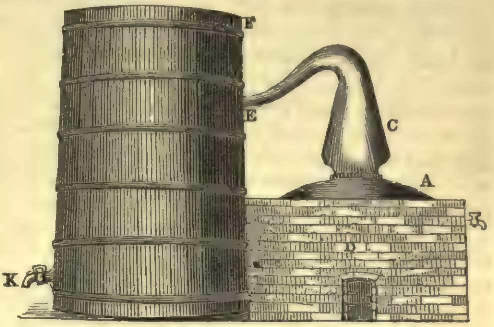
Examinations in distilleries are constantly being made by the officers of Excise. The first survey is at six o'clock in the morning, when the officers take their accounts and gages, and make calculations which occupy several hours; the second is at ten o'clock, when they inspect the whole premises, occupying a considerable time, frequently staying till the succeeding officer comes on duty; the third takes place at two in the afternoon; and the fourth, at six in the evening. At ten, an officer who has not been engaged in any of the previous examinations, makes his appearance, and prolongs his visit till six the next morning. In addition to these regular inspections, the distilleries are subject to frequent and uncertain visits of the surveyor and his general.

Before the fermented wort goes into the still, a calculation is made of the quantity of wash drawn from the wash-back, and which is first pumped into what is called the wash-charger. If the liquor in the charger exceeds the quantity in the back, the distiller has to pay on the higher amount; if it contain less, he must pay according to the wash-back, as being the larger quantity. When all the wash is transferred to the charger, its exit tap is unlocked, and the wash is allowed to be drawn off into the still; the charging and discharging tap of the still being fastened by the officers, there can be no transfer of wash but through the pumps. The first distillation from the wash is worked into the low-wine receiver, and the strength and quantity are ascertained by the Excise officer. The account of the low-wine affords a comparison with the quantity which the contents of the wash-back had been estimated to produce. This is then pumped from the receiver into the low-wine charger, and after the officer has performed his duty, it is permitted to be drawn off into the low-wine still, which is a distillation of the second extraction; the low-wine still then works into another cask, called the spirit-receiver; when that distillation is finished, the officer, reattending on regular notice for that purpose, takes the quantity and strength of the spirit therein, and upon the quantity so ascertained he charges the duty. If it happens that the actual quantity of spirit, after the distillation, differs from the hypothetical quantity ascertained by previous calculations, he gives to the Government the benefit of the doubt, and levies duty on the higher quantity, whichsoever that may be. The mode in which this double system of computation is likely to check improvements, forms a delicate subject, and therefore will not be further discussed. In distilling low wines, one portion of them goes into the spirit, and another into the faints-receiver; these faints are, in the next distillation, united with the low-wines from the succeeding wash-back, and are worked together; the united produce goes partly into the spirit-cask, and partly back into the faints-cask. The operation is thus continued till all the backs are emptied. All these backs, chargers, receivers, *et cetera*, are secured by locks, the keys of which are kept by the Excise officer.

The still has been in use from a very remote period; but those in operation at present are quite different from the ones of former days. Changes in the construction of the still are chiefly the result of the onward course of science, and the increased requirements of the age.

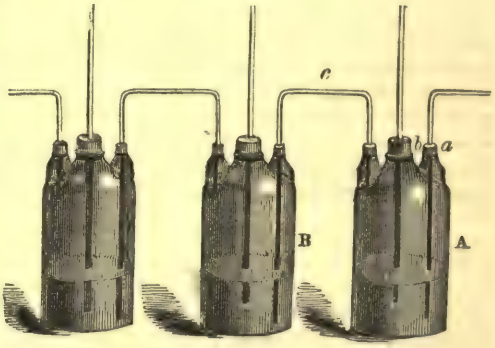
Fig. 44 is a drawing of the common still: A is the body incased in brickwork, D, and directly over the fire; C, the head attached to the condensing-worm, E, placed in the water-tub, F, where the vapor is condensed to a liquid which flows into a receiver at K. The still is of variable dimensions, from ten to five hundred gallons. This form of apparatus had been in use for a considerable period. WOULFE, having the principle of GLAUBER's apparatus in view, was the first to apply the facts already cited, for obtaining strong spirit, and various other products of distillation.

Fig. 44.



This apparatus bears the name of the inventor to the present day. It is shown in Fig. 45, and consists of a series of bottles, placed in a range. Each of these bottles has three openings or necks; the first bottle is connected with the beak of the still by a pipe or tube, which passes through the neck, *a*, to within an inch or two of the bottom. A safety-tube is introduced through the neck, *b*, and dips into the liquid in the bottle. The bottle, A, communicates with the bottle, B, by means of a pipe or tube, *c*, bent at right angles; in the first it opens a little below the cork, but in the second it passes nearly to the bottom. The second is joined in a similar way to a third and fourth bottle, if required. This apparatus is in daily request in the laboratory, for the purpose of obtaining aqueous solutions of gaseous bodies. It was from it that M. EDOUARD ADAM conceived the idea of his complex still; and the same principle is to be observed in all the various modifications of stills constructed in the beginning of the present century, the most important of which will be described.

Fig. 45.



In this kingdom, the modifications in the construction of stills have been various. Previous to the year 1788, the old form of still was in general use. From the slowness of the distillation, a week elapsed before a charge was completely worked off, and even then the products were very dilute. At this period the Excise duty levied was according to the size of the still, and no further trouble was taken by the officers as to how the worts were made, except that they visited the distilleries occasionally, to observe if any other stills were in operation, or if larger ones were substituted for those which had been already gaged. About the above period an important revolution took place in the construction of this apparatus by a firm in Leith, by which the distillation was very much expedited. They lessened the height and increased the width of the still, to expose a larger surface to the action of the fire than could be done in the old form; the head of the still was enlarged in proportion to the quantity of vapor generated, and occasionally several outlets or pipes were inserted around the horizontal upper part, to facilitate the escape of the steam and alcoholic vapor into the condensing worm. This still could be charged, distilled off, and be ready for another operation, in the course of a few hours, instead of a week as before with the common still. Though the inventors preserved to themselves its exclusive use for about twelve months, yet such an important discovery could not escape the vigilance of competing neighbors, and hence it shortly afterwards became general in Scotland. The Excise, until they became apprised of the fact, were outwitted, the distillers, as might be expected, pocketing the duty which they otherwise should have paid for the excess of spirits distilled above the ordinary allowance to which the former method of gaging subjected them. The Excise duty, however, was soon altered, and year after year it increased; but the distillers, constantly upon the alert, were enabled to hoodwink the overseers appointed by Parliament, which was driven to the necessity of nominating a committee, in 1799, to investigate this branch of the Excise laws, and which furnished a lengthy report of the facts concerning the modes of distillation in Scotland. In consequence of this report the distillers were subjected to an Excise duty according to the capacity of the still, and on the supposition that it would be worked off and charged every *eight* successive minutes during the distilling season. Even this time was considerably shortened by the distiller; still, the amount of fuel consumed, and the consequent wear and tear, left it a matter of doubt whether they were gainers by it. The rapidity of this method was carried so far, that, in 1815, the last year of the license duty, a still of eighty gallons capacity could be distilled off, emptied, and be ready for a successive operation in three and a half minutes, sometimes in three minutes! A still of forty gallons could be drawn off in two and a half minutes. An alteration in the Excise laws at this time did away with the license duty, and the law became the same as in England, of levying duty upon the wash and spirits procured therefrom, which dispensed with the rapid mode.

In the meantime, the stills were constructed on the plan of those in use during the period of rapid distillation, namely, by having the bottoms wider than the English stills, in proportion to their size.

From the interest which, at one time, was attached to the Scotch still, on account of the ingenuity displayed by the inventors, and its being a source of much investigation to the Government committees, it may not be out of place to gratify the curiosity of the reader by introducing to his notice a drawing and brief description of the apparatus. As the general principles of the nature of the still have been already given, a recurrence to them is unnecessary.

The subjoined Figs., 46 and 46^a, represent a sectional and front view of the Scotch still, at the period when rapid distillation was popular amongst spirit manufacturers. E E is the body of the still, the bottom of which is about sixteen feet in diameter, and convex towards the middle; the depth of the still at the centre is about eleven feet, and the sides and bottom meet at an acute angle at the verge. The hollow bottom of the still is connected with the shoulder, B, by solder, or rivets, but in so firm a manner that the connection is air-tight; C, a rim, which serves to support the still, as likewise to protect it from the action of the

Fig. 46.

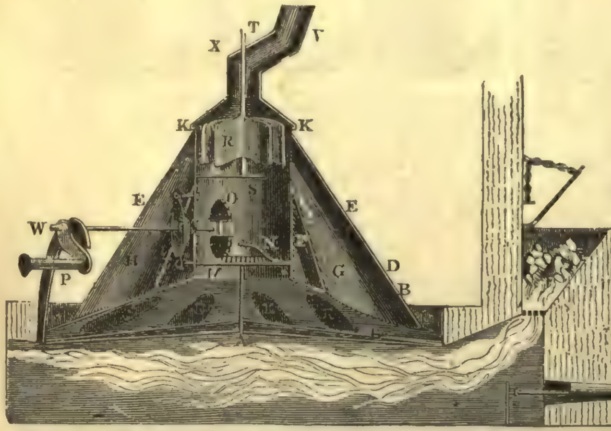
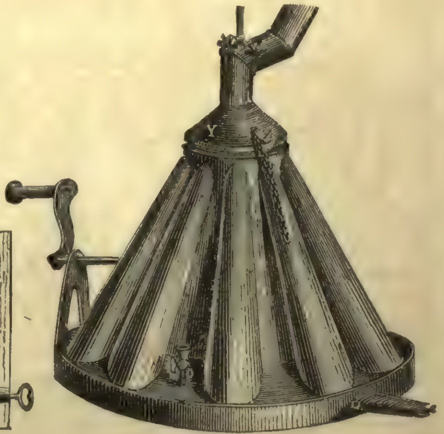
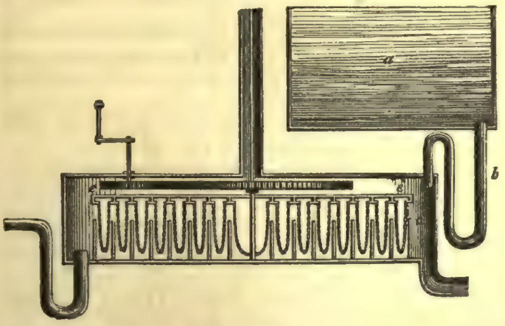


Fig. 46a.



fire. D is the discharging pipe, seen in the front view of the apparatus, but concealed in the section. In the shoulder of the still are several elliptical openings, to which are attached oblique conical tubes, that enter a cylinder which rises from the centre of the boiler; G is a vertical section of one of the pipes, which are soldered or connected at the bottom to the opening in the shoulder of the still; and F, a section of the central column; H is an exterior view of another of the side pipes; I I I I are lower openings of four others of these, and K K the top openings in the central column; L, an agitator within the still, to keep the bottom free from sedimentary matters,—a chain agitator was sometimes substituted, which, with a little alteration, was found to work much better; M, a vertical axis of the agitator, to which a horizontal toothed wheel, N, is attached; O is another such cogged wheel, but vertical, gearing into the wheel, N, so as to communicate its motion to the latter when required; P, a handle fixed upon the axis of the wheel, O, by which it is turned; W, support of handle and axis; R, a fan to break the froth formed by boiling; its axis rests upon the cross-bar, S. Motion is given to the fan by the vertical axis, T; this axis enters the large pipe that carries off the vapors, through a packed box, X, which is impervious to the escape of any steam or vapor; a similar box surrounds the axis of the wheel, O; V is the pipe communicating with the condensing-worm, and through which the vapors escape to be condensed. The funnel pipe, O, shown in the perspective view, serves to charge the still, and Y is the cover of the central column, which is held in its proper position by chains, as seen at Z.

Fig. 47.

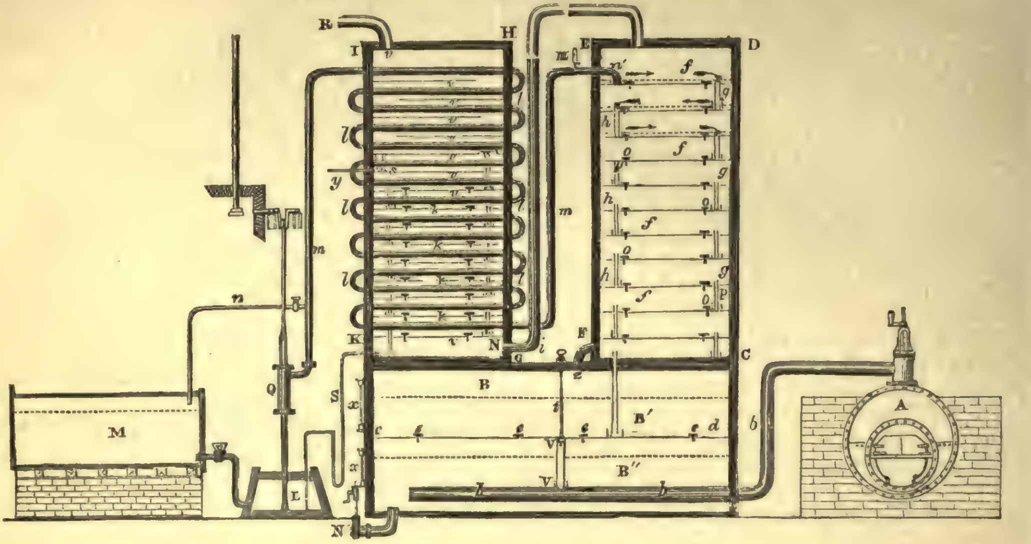


An adaptation of this still, by Sir Anthony Perrier of Cork, is shown in Fig. 47, in which the liquid to be distilled is made to flow gradually and continuously over the heated surface of the boiler, while it parts with its alcohol. The bottom of the boiler is divided by concentric partitions, which stand up sufficiently high to prevent the liquid from boiling over; these partitions have openings from one to another at opposite sides, so as to make the course a sort of labyrinth. *a* is the reservoir of liquor prepared for operation; *b*, a pipe descending from this reservoir, which conducts the liquor into the boiler at *c*, the commencement of the labyrinth, in flowing through which it progressively traverses the whole surface of the bottom, so that the full effect of the fire is exerted upon small portions of the liquid. This causes the evaporation to proceed with great celerity, and when the liquid has reached the discharge-pipe at the opposite side, it retains no spirit. The series of chains suspended from the bars, *e e*, which are supported by the central shaft, prevent the deposit of mucus and albuminous matters on the bottom of the still. A toothed wheel and pinion communicate motion to the bars, *e e*, through the shaft, and the chains sweep the compartments between the partitions as they turn round.

The first step towards obtaining the products of distillation in a concentrated state by a novel arrangement of the still, or rather condensing apparatus, was taken by Mr. Coffey of Dublin. In all the preceding stills, although the rapidity of distillation had reached the acmé of perfection, yet the great disadvantage of having the aqueous and alcoholic portions of the distillate mixed up, remained; and only by great trouble and repeated distillations and changing of receivers, a strong spirit could be obtained. Coffey's method was to insert two pipes in the first and second rounds of the condensing worm, which pipes were in communication with the body of the still. This simple contrivance insured considerable advantage, as a great portion of the aqueous vapors eliminated from the boiling liquid in the still, was removed from the alcoholic portion by being condensed in the first convolutions, and returned to the still instead of flowing into the receiver with the spirit.

Subsequently, Mr. Coffey patented another still, which has proved most serviceable to the distiller, as it gives, in continuous distillation, the strongest spirit that can be obtained on the large scale. Fig. 48 is a section of this still. The body of the apparatus consists of an oblong vessel, B, and two columns erected thereon, C D E F and G H I K. The first of these columns is called the analyzer, the second the rectifier. The whole is made of wood, lined with copper, and the wood being five or six inches thick, little or no heat is lost by radiation. The oblong vessel has a copper plate or diaphragm, *c d*, across the middle of it, which divides it into two chambers, B′ B″. This diaphragm is perforated with a great number of small holes, for the passage of the vapor upwards during the process, and it is also furnished with several valves, which open upwards, as shown at *e e e e*, whenever the vapor is in such quantity as not to find a free passage through the perforations. A pipe, V V, descends from this diaphragm nearly to the bottom of the lower chamber, into a pan forming a steam trap; and there is a valve on the top of this pipe, which can be opened or shut at pleasure, by means of a rod, *t*, passing through a stuffing-box on the top of the vessel. Glass tubes, at *x x*, show at all times the level of the liquor in the chambers, B′ B″. The column, C D E F, which is called the analyzer, consists of twelve chambers, *f f f f*, formed by the interposition of eleven copper diaphragms, *g h*, *g h*, *et cetera*, similar to the large diaphragm, *c d*; that is to say, these eleven diaphragms are perforated with very numerous holes, and furnished with valves, *o o o o*, opening upwards. To each of them is also attached a dropping pipe, *p*, by which the liquor is allowed to flow from plate to plate; the upper end of each of those pipes projects an inch or two above the plate in which it is inserted, so as to retain, at all times, during the distillation, a stratum of wash of that depth at each diaphragm The lower end of each pipe dips a little way into a shallow pan lying on the diaphragm underneath, forming thus a steam trap, by which the escape of vapor through the pipe is prevented. The pipes are inserted at alternate ends of the diaphragm, as shown in the figure.

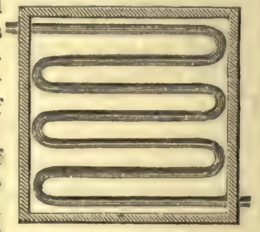
Fig. 48.



The column, G H I K, is divided, in a similar manner to that just described, into chambers, by interposed copper plates or diaphragms. There are fifteen chambers in this column; the lowermost ten, *k k k, et cetera*, constitute the rectifier, and its diaphragms are perforated, and furnished with valves and dropping pipes, precisely similar to those of the analyzer. The uppermost five of these frames form the finished spirit condenser, and are separated from the other ten by a copper sheet or diaphragm, without small perforations, but having a large opening at W, for the passage of spiritous vapor, and a dropping pipe at *s*. There is a neck about the opening, W, rising an inch or so above the surface of the diaphragm, which prevents the return of any finished spirit by that opening. Under the dropping pipe, *s*, is a pan much deeper than those of the other dropping pipes, and from this pan a branch pipe, *y*, passes out of the apparatus, and carries the condensed, but still very hot spirits, to a worm, or other refrigerator, wherein they are cooled. The chambers, *v v v v v*, of this finished spirit condenser, are formed of plain unperforated diaphragms of copper, with alternate openings at the ends, large enough both for the passage of the vapor upwards, and of the condensed spirit downwards; the use of these diaphragms being merely to cause the vapor to pass along the pipe, *m m*, in a zig-zag direction, and to be thus more perfectly exposed to its condensing surface.

In every chamber, both of the finished spirit condenser and of the rectifier, there is a set of zig-zag pipes, placed as shown in the plan, Fig. 49. Each set of these pipes is connected with the others by the bends, *l l l l*, thus forming one continued pipe, *m m*, leading from the wash pump, Q, to the bottom of the rectifier, whence it finally passes out, and rising up, enters the top chamber of the analyzer, where it discharges itself at *n'*. M is the wash charger; L, a smaller wash vessel connected with it, and with the wash pump. This vessel is called the wash reservoir, and is not, strictly speaking, a necessary part of the apparatus; its use is to retain a sufficient reserve of wash, to prevent the apparatus being idle during the delay, which the Excise regulations render unavoidable, between the emptying of the wash charger and the refilling it from a new back.

Fig. 49.



The pump, Q, is worked continuously during the distillation, so as to supply the apparatus with a regular stream of wash. It is so constructed as to be capable of furnishing somewhat more than is necessary, and there is a pipe, *n*, with stopcock, by which part of what is pumped up may be allowed to run back, and the supply sent into the apparatus regulated.

A is a steam-boiler, having nothing peculiar in its construction. The steam from it is conveyed into the bottom of the spent wash receiver by the pipe, *b b*, which, after entering the receiver, branches into a number of smaller pipes, perforated with holes, by which the steam is dispersed through every part of the wash in which they are immersed. These perforated pipes are not shown in the drawing.

Mode of Action.—When commencing an operation, the wash pump is set in motion, to charge all the zig-zag pipes, *m m m*, until the wash passes over into the analyzers at *n'*. The pump is then stopped, and the steam let into the bottom of the apparatus by the pipe, *b b*. The steam passes up through the chambers, B'' B', and by the pipe, *z*, into the analyzers, whence it descends, through *i*, to the bottom of the rectifier at N. It then rises through the chambers, *k k*, enveloping the zig-zag pipes, and rapidly heating the wash contained in them. When the attendant perceives, by feeling the bends, *l l l*, that the wash has been heated in several layers of these pipes, perhaps eight or ten layers—but the number is not of much moment—he again sets the pump to work, and the wash, now boiling hot, or nearly so—and always in rapid motion—flows from the pipe *m* at *n′*, and passes down from chamber to chamber through the dropping pipes, in the direction shown by the arrows in a few of the upper chambers. It may be here observed that no portion of the wash passes through the small holes perforated in the diaphragms which separate the chambers. These holes are regulated, both in number and size, so as not to be more than sufficient to afford a passage for the vapors upwards, under some pressure. The holes, therefore, afford no outlet for the liquor, which can only find its way down in the zig-zag course indicated by the arrows. It is therefore obvious, that the wash, as it passes down, is spread into strata as many times as there are diaphragms, and is thus exposed to the most searching action of the steam constantly blowing up through it. As it falls from chamber to chamber, its alcohol is volatilized by the steam passing upwards; and by the time the wash has reached the large chamber, B, no trace of the spirit remains. The wash, as it descends from the analyzer, accumulates in the large chamber, B′, until it becomes nearly filled, which, when perceived to be the case, by the inspection of the glass tube, the attendant opens the valve of the pipe, V, and discharges the contents of B′ into the lower compartment; then shutting the valve, the wash from the analyzer again accumulates in B′, and, when it is nearly full, the contents of the lower chamber are discharged from the apparatus altogether, through the cock, N′, and the charge in B′ let down by opening the valve, V, as before; thus the process goes on so long as there is any wash to supply the pump.

When all the wash is gone, a quantity of water is let into the reservoir, L, and pumped through the pipes, *m m*, to finish the process, and obtain the last portions of alcohol. This winding up of the operation by sending water through the pipes, takes place on the distillation of every back of wash, in consequence of the Excise regulation, which requires the distiller to keep the produce of each back separate from that of any other. Were it not for this regulation, the distillation would go on uninterruptedly, so long as there was any wash in stock; the addition of water for winding up would be necessary but once during the distilling period, and the manufacturer would save much time and fuel at present wasted by these interruptions.

It has been already said, that in the ordinary course of the operation, the wash is stripped of all its alcohol by the time it has reached the bottom of the analyzer; but, as a precautionary measure, the chambers, B′ B″, have been superadded, in each of which the spent wash is exposed for about half an hour to the action of the steam blowing through it. There is a small apparatus —not shown in the engraving—by which a portion of the steam in the chamber, B″, is condensed, cooled, and made to flow constantly through a sample jar, in which is an hydrometer, or, what is better, two glass bulbs, one of the spec. grav. 1·00, and the other, 0·998. The attendant knows all is right when the lighter of these bulbs floats in the sample; hence the chamber, B, may be emptied without any risk of loss.

The course of the wash being understood, that of the steam will require very little description.

The steam, as it rises, is first blown through the charges of spent wash in the lower chamber of B, thence it passes up through the layers of wash on the eleven diaphragms of the analyzer. In its course it abstracts from these layers of wash, their alcohol, depositing in its place an equivalent of water. After traversing the whole of the analyzer, the vapor, now containing much alcohol, passes, by the pipe, *i*, into the bottom of the rectifier, and, as it ascends, it envelopes the pipes *m m*, heating the wash, and simultaneously parting with its more watery portion, which is condensed, and falls, in a state of ebullition, on the several diaphragms of the rectifier. By the time the vapor reaches the passage, W, in the bottom of the finished spirit condenser, it is nearly pure alcohol; and as it is condensed by the wash in the pipes, and falls on the diaphragm, it is conveyed away by the pipe, *y*, to a refrigerator. At the top of the spirit condenser is a large pipe, R, which serves as a vent for the incondensable gas which is disengaged in the process, and this pipe also communicates with the refrigerator, so that, should vapor at any time be sufficient to pass out of the apparatus, no loss is sustained beyond the waste of fuel caused by condensing that vapor by the water of the refrigerator, instead of the wash of the condenser.

The liquor formed on the several diaphragms of the rectifier, after the vapor, passing up from plate to plate, has blown through it, descends to the bottom in the same manner as the wash falls from chamber to chamber in the analyzer: but this condensed liquor still contains a portion of alcohol, and it is conveyed by the pipe, S, to the pump, Q, by which it is raised up with the wash, to be again distilled.

A thermometer at *m′* shows the attendant the temperature of the wash as it issues from the pipe, *m m*, into the analyzer, which is the only guide he requires for managing the operation; for, when the temperature is what it should be, nothing can go wrong in the work. Whenever the thermometer indicates too high a temperature, more wash should be let into the apparatus, and *vice versâ*—the quantity being regulated by the tap and the pipe, *n*. It would seem, however, that very little nicety is requisite on this point. Experience has proved, that the fluctuation of a few degrees above or below the proper heat is of little consequence, and that it is very seldom found necessary to alter the supply of wash.

The water for supplying the boiler passes through a long coil of pipe immersed in boiling-hot spent wash, by which means it is raised to a high temperature before it reaches the boiler. It will be seen that the vapor passing through this apparatus is all condensed by the wash, not water; and, therefore, no heat is wasted, as in the common process. The consequence of this is, that about three-fourths of the fuel used with the common stills are saved, a matter of very important consideration in a national point of view.

According to the common process, it requires twelve pounds of coal to distil a gallon of proof spirits—when coals of a superior quality are employed, and the stills are scientifically constructed, less will suffice—of which, as has been said, nine pounds are saved by the new system; and assuming the whole quantity of spirits distilled in the empire to be thirty-six million gallons, which—colonies included—is not over the mark, the saving of fuel arising from the new methods of distilling, which, no doubt, will be soon universally adopted, will amount to one hundred and forty thousand tons of coal per annum.

Very few persons have any idea of the enormous size of some of the distilleries in the United Kingdom. One of Mr. COFFEY'S stills, at Inverkeithing, works off two thousand gallons of wash per hour, and one which the inventor has subsequently erected at Leith, for the same proprietors, upwards of three thousand gallons. There are several of equal magnitude, and it is stated that those now at work, or being erected, are capable of distilling half a million gallons of wash per day—this wash yielding, on an average, from eleven to twelve per cent. of proof spirit.

The great difficulties distillers in general had formerly to contend with, are no longer encountered, as the advancement of science necessarily improves every branch of industry. No one can observe the difference of the condensation of aqueous and alcoholic vapors, and look at the various apparatus of the present time, without coming to the conclusion, that chemistry, in particular, has conferred very great improvements in distillation.

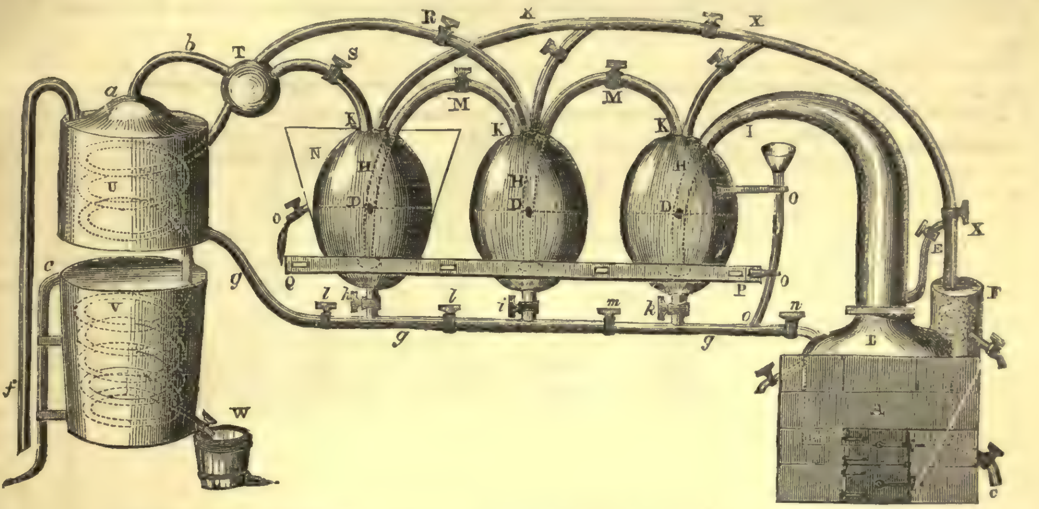
The continental savans were the first to offer improved forms of stills. Relative to the distillation or production of ardent spirits, the improvements are principally of two kinds: firstly, relating to the construction of proper apparatus, by the use of which spirit of a superior strength is obtained from the first distillation, without the trouble of repeated distillations, as in the older methods; and secondly, the knowledge acquired in employing the most economical quantities of materials from which spirits are obtained in this country, as well as in the proper fermenting operations to which such materials are subjected previous to distillation.

M. POISSONIER, in the year 1779, proposed a modification of the common still, and deemed his plan to be the ultimate pitch of perfection of which the still was susceptible. His modification would most likely have come into general use, had it not been for the better and more ingenious invention of M. ADAM, an obscure person of Nîmes, who was devoid of scientific knowledge, and, though a distiller, was ignorant of the art which he improved. Being an auditor of a course of chemical lectures at Montpelier, during which the merits of a WOULFE'S apparatus as a condenser were discussed, he conceived the idea of constructing a still in which the principles of the apparatus of GLAUBER and WOULFE should be applied in the condensation of the vapor. Accordingly, he diligently applied himself to the construction of an apparatus on these principles, and, after repeated additions and alterations, it was found to answer the intended purpose. He took a ten years' *brevet*, or patent, in 1801, for his invention, and since that time a complete revolution has been effected in the art of distillation. About the same time, M. SOLIMANI obtained a patent for another form of distillatory apparatus. This gentleman was a physician at Nîmes, and formerly lecturer on chemistry and experimental philosophy, and disputed the priority of his invention with M. ADAM; but his patent is dated a few days later in July, 1801, than ADAM'S. Various other modifications of the still and condensing apparatus were introduced, the most important being that of M. BERARD, which he patented on the 16th of August, 1805.

ADAM'S still, however, continued to be most in use, not so much on account of its merits—for it was considerably inferior to SOLIMANI and BERARD'S—but owing to the quarrelsome disposition of the patentee, whose cupidity led him to suppose, as his brevet specified that the whole of the alcohol could be obtained from wines when distilled in his apparatus, that the other inventions were an infringement on his rights; and the lawsuits to which he exposed those using any new invention, prevented the general use of any other than his own. This litigiousness of M. ADAM, however, became afterwards his just corrector; for, after realizing a handsome fortune by his own distillery and the proceeds of his patent, he became so immersed in lawsuits, which ultimately proved unfavorable, that, with the expenses and costs of these heavy cases, he was completely reduced.

Fig. 50 is a drawing of ADAM'S still: B is the body of the still, incased in brickwork, and is heated by the furnace, A. The head, I, of the still carries off the vapor to a series of egg-shaped vessels of copper, H, H, H, the first of which it enters at the top, and terminates at the bottom in a perforated rose, like that of a watering-pot, the holes being about an eighth of an inch in diameter. The first vessel is connected with the second, and the second with the third, by the pipes, K, M, proceeding from the top of each, and terminating at the bottom of the next, in the form of a rose, similar to the pipe, I, the tubes fitting air-tight into them. They are supported on a framework, Q P, the wider end being uppermost. D, D, D are cocks, to show when they are half-full. The last vessel—here the third—is furnished with a bucket, N, soldered to its upper end, and filled with water, to condense the vapor; the hot water is drawn off by the stopcock, O. When the still is furnished with four or more oval-shaped vessels, the last two have refrigerators attached to them; if strong spirit be not required, the third may be dispensed with. The pipes, S, R, furnished with stopcocks, connect the second and third vessel with the globe, T, from which the worm in the covered vessel, U, proceeds. V is a large tub, which contains the second worm, being a continuation of the one in the vessel, U, and is filled with cold water by means of a water-pipe, entering at the bottom, though not shown in the figure; and as the water gets warm, it is discharged by the pipe, *c*. Another pipe, *a b*, issues from the head of the vessel, U, and is inserted in the globe, T, a continuation of which, though not expressed in the figure, connects this globe with the body of the still, or with either of the egg-shaped vessels, at pleasure; *ggg* connects the vessel U with the body of the still, as also with H, H, H, by means of the branching pipes from their bottoms, which are furnished with stopcocks, *h*, *i*, *k*; the stopcocks, *l*, *l*, *m*, *n*, in the pipe *ggg*, serve to regulate the connection with either of these vessels, as occasion requires it. The pipe and stopcock in the shoulder of the boiler regulate the proper quantity of wine to be introduced; and C, another pipe and stopcock, serves to run off the *vinasse*, or spent wine, from the still, when all the spirit has been eliminated. Another pipe, X X X, connects the three vessels, as well as the capital of the still, with a small worm placed in the vessel, F, the connecting branch pipes being furnished with stopcocks, to open or close a connection with any of the vessels. O O is a funnel pipe, which serves to charge the apparatus with *repasse*, or weak brandy, and is joined with the first, H, and the frame, Q P, by iron stays. The whole of the still and condensing apparatus is constructed of tinned copper, and the pipes connected by solder.

Fig. 50.



Operations are begun by opening the stopcocks, *l*, *l*, *m*, *n*; also, the pipe in the shoulder of the boiler, and closing the cocks, *h*, *i*, *k*; the vessel, U, is then filled with wine from the storehouse, through the supply pipe inserted in the cover, by means of a forcing pump, till the wine flows out by the pipe in the shoulder of B; this is then closed, and the cocks, *k*, *i*, *h*, opened in succession, till the wine flows out at D D D, the stopcocks, *n*, *m*, *l*, being closed as the still and first and second vessels are filled in succession. The pumping of the wine is continued until the vessel, U, is nearly filled; afterwards the refrigerators, N and V, are replenished with cold water. Everything being thus prepared, all the lower cocks are closed, and the upper stopcocks, M, M, R, S, opened, in order to allow a free passage for the vapor; the fire is then urged on till the liquor in the still begins to boil. The first portion of vapor is richer in spirit, and this passing into the first H, by the capital I, is condensed. The wine in this vessel—which is heated by the vapor rising from the boiler—contains a greater proportion of alcohol, on which account it boils quicker, and cannot reach as high a temperature as the liquid in B. The eliminated vapor from the first H, in consequence of the low temperature at which it is generated, contains less water, and this being condensed in the second, renders the wine which it contains much stronger than that in the first, and boils at a still lower heat. The more aqueous portion of the vapor from the second H, passing off by the connecting pipe, K M, is partly condensed in the third, while the surcharged alcoholic vapor enters the condensing worm in the vessel, U, through the pipe, S, where it is condensed, and flows out into the receiver, W. This is tightly covered over to prevent evaporation of the alcohol; and in order that the stream of liquid condensed may be seen, a glass pipe connects the lower end of the worm and the receiver. As soon as the distilled product, when examined by the hydrometer, shows a diminution of strength, the receiver is changed, and the weaker liquor, or *repasse*, is collected by itself, and submitted to a second distillation. The strength of the liquor in the boiler, B, or in any of the condensers, may likewise be ascertained by means of the pipe, X X X, which proceeds from the last, and communicates with the small worm, F, beside the body of the still; from each of the others, as also from the capital, pipes open into it, and as these are each furnished with stopcocks, the vapors from any particular condenser, or the still, may be liquefied in the small worm, F, the other communications being cut off. The spirit as it flows out at the end of this worm is received in a testing glass, and examined by the hydrometer, or by other means. When the liquor in the body of the still is exhausted, the fire is withdrawn, the other communications with the oval-shaped vessels and great worm are cut off, and the cock, C, opened to draw off the *vinasse*, or residue. If it also appears that the liquid in any of the condensers is exhausted, it is run off to the body of the still by turning the stopcocks appended to it. The still is next charged by allowing the unexhausted liquor in H, H, H, to flow in through the pipe, *ggg*, and the remainder, sufficient to fill the boiler as before, is supplied from the vessel, U. H, H, H may be half filled with brandy, or *repasse*, through the funnel pipe, o o; after which the lower taps are closed, and the upper ones opened as before, and the distillation continued. During the transmission of the alcoholic vapor through the wine vessel, U, the contents become heated, and some spiritous vapor is given off, which may be conducted into the body of the still, or any of the condensers, as deemed desirable, by the pipe *b*, the continuation of which is not expressed in the drawing.

When weak spirit is required, the communication with the third H is cut off by closing the stopcocks, M, S, and opening R, and when an extra strong liquor is required, a fourth condenser is supplied; for, according to the statements of the patentee, the more condensers that are furnished, the better and more completely will the rectification be effected. The body of this kind of still is stronger than ordinary, in consequence of the pressure from the egg-shaped vessels, which, of course, renders the expansive force of the vapor greater.

An elevation of the apparatus of SOLIMANI is represented in Fig. 51, of which Fig. 52 is a section. The distillation is effected by the heat of boiling water. Four stills constitute the set; these are A, A, B, B, in the section, placed two at each side of the chimney, T. Each pair of stills is connected at the bottom by the pipes, E, E′; the body of each still is about four feet square and eighteen inches deep, and rests upon stout iron bars, *c c c*, firmly fixed in the walls of the furnace. *d d d′ d′* are the necks of the stills; they measure about three feet in breadth, and are long enough to rise above the stone vault, *f*, which protects the stills from view in Fig. 51. The heads are rather low, and the curvature, *g g g′ g′*, rather wide; they are soldered to a large pipe, H H′, which conducts the alcoholic vapor to the copper vessels, K K′, forming a part of the condensing apparatus. Some of the vapor is condensed in these vessels, and forms a liquid layer on the bottom, through which the remaining vapor has to force a passage. F F′ are large pipes for carrying off the uncondensed gas into the vessels, I I′, wherein is contained the condensing apparatus, or *dephlegmator*. Another small pipe, not shown in the figure, carries off the vapor from I I′ into the condensing medium, immersed in water contained in the stone cistern, M; and the small pipes, *a a′*, supply the cold water to the vessels I I′ from M.

Fig. 51.

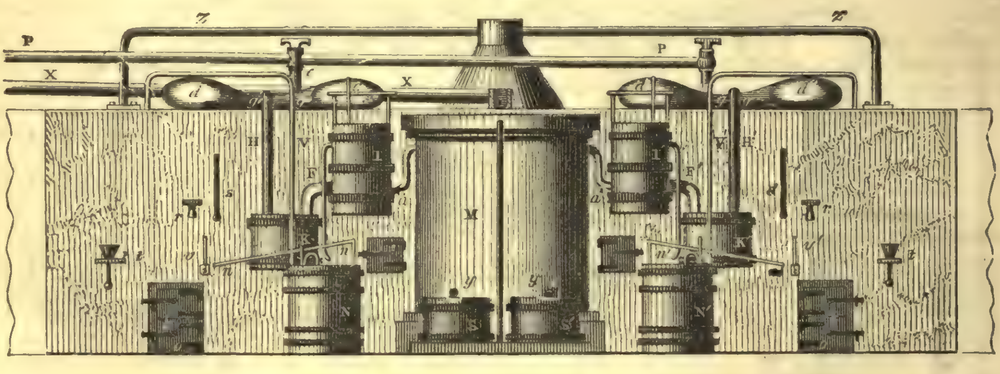
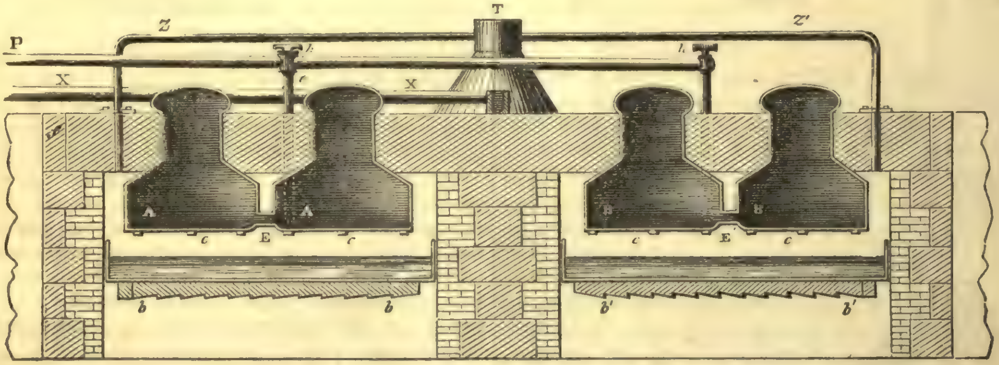


Fig. 52.



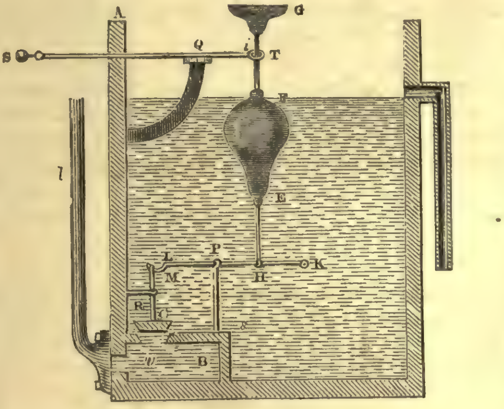
The stills are charged with wine through the main pipe P, which branches into them. By turning the stopcocks of this pipe, either pair of stills may be charged with wine, as the pipe, *e*, and the termination of P, reach nearly to the bottom of the body of the stills. The pipe, X X, supplies the large cistern, M, with cold water.

The condenser in each of the vessels, I I′, is kept cool by a self-acting apparatus, that admits the water from the cistern, M, in the requisite proportion to cool the parallelogram condenser.

The stills are heated by two boilers, about ten feet long and four and a half wide, which contain about eight to twelve inches of water in depth. *b b b′ b′* show a portion of the flue, which, at the fire, is about eight inches square, and gradually gets narrower as it approaches the chimney. The length of the flue from the fire to the chimney is about thirty-six feet, being brought several times back and forth under the boilers, that no heat may be lost. *z z′* are pipes for carrying off the steam into the chimney.

During the time the stills are in the course of being charged, the water in the boilers is raised to a temperature of 212°, and the steam which is generated, circulating around the stills, heats them so as to bring their contents to a boiling temperature in a very short time. The alcoholic vapor that rises flows down through H H′ into the vessels, K K′; part of it is here condensed, and the remainder which continues rarefied enters the first condenser through the large pipe, F F′. All the condensed liquid that is formed in this refrigerator flows back through the pipes, F F′, into K K′, where it collects till it rises as high as the bend of the attached siphons, when it flows into the large covered tanks, N N′. After the condensed weak and impure spirit has accumulated in N, it is pumped into the stills by means of the pumps, *n n n′ n′*, through the pipes, V V′, to undergo a second distillation. *i i′* are doors, by which to enter when any repairs are required by the boilers, *et cetera; k k′*, the doors of the furnaces for heating the boilers, and *o o′*, the ashpits. The pipes which discharge the spent wine from the stills are seen at *r r′*, and the gage, or glass tube, *s s′*, shows what height of liquid they contain. The funnel pipes, *t t′*, serve to introduce water into the boilers, which are furnished, like the stills, with glass gages, *v v′*, to show the height of water inside.

Fig. 53.



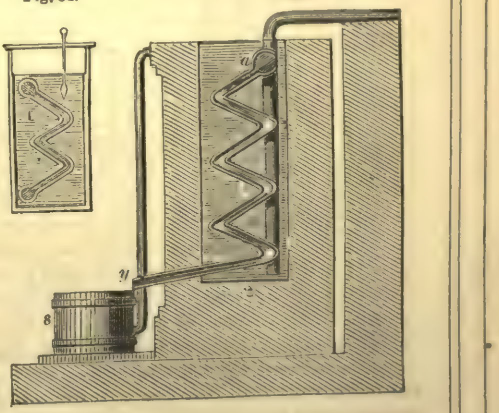
A, Fig. 53, is a section of one of the vessels, I, on one side of the condensing apparatus. B is a box fixed on the bottom, having a valve, C, in its upper part, of sufficient weight to resist the force of the stream of water entering the box by the pipe, *l*, from the large condensing trough. E F is a floating ball, bearing on its upper stem, G F, a basin, G, for the reception of weights. The lower stem of the float has a ring at the end, H, through which a sliding rod, K L, passes; this rod has a weight at the end, K, and a hook at L, which passes through the ring in the upper end of the rod, M, attached to the valve, C; K L is supported in the centre by the upright, P; R is a horizontal rod, which retains the valve, C, in its proper position, by means of the stem of the latter passing through a ring at the end of R. A sliding rod, S T, is inserted in the side of the vessel; this rod has a ring, *i*, at its end, through which the upper stem of the float, E F, passes, and is supported by the arm, Q. The principle of the working depends on the rarefaction of the water when heated, and on the proportionate decrease of specific gravity. Weights are placed on the basin, G, to counterpoise the float at the exact temperature at which it is desirable to have the water. When the water gets hotter than this, the float descends, and pressing on the lever rod, K L, at H, raises the valve, C, when the water from the pipe, *l*, enters; when sufficient water has entered to cool down the vessel to the proper degree, as regulated by the float, the valve closes.

In case the float is found not to act properly, or that the water rises considerably above the temperature to which the weights on the basin correspond, the rod, S T, is to be pushed further into the vessel, which moves the lower end of the float towards K, and by this means greater force is applied to raise the valve C, in order that cold water may enter.

The condensing apparatus, or dephlegmator, in the vessels I I′ and M, in Fig. 51, consists of two broad sheets of tinned copper soldered together, so as to leave only one-sixth of an inch between them. In the vessels I I′, the dephlegmator forms four inclined planes, and in M M′ it is composed of six. These are the more advantageous on account of the extent of surface which is exposed to the condensing action of the strata of water. Figs. 54 and 55 show the position of these condensers.

Having described the still and condensing apparatus, the manner of working will now be shown. The boilers being replenished with water to the depth of about eight inches, the fire is urged under them; during the time this is being done, wine runs into the still through P and *e*—Fig. 51—till it reaches the proper height, as

Fig. 54. Fig. 55.



indicated by the gage *s*, when the taps of the supply pipe are turned off. As soon as the water begins to boil, the contents of the still are likewise heated, and the vapor produced is forced to descend by the pipe, H, into the vessel, K, where some of the aqueous portions are condensed. The remaining portion of the vapor traverses the layer of liquid in its passage into the condensing vessel, I. Here the excess of steam is condensed, and flows back into the vessel, K, through the pipe, F; and when the weak and impure spirit collects in this to that extent that it rises as high as the bent siphon tube, it is discharged into the tank, N, whence it is again returned to the still by the pump, *n n*. But very little spirit is condensed in I I′, when the apparatus in this vessel for the regulation of the supply of cold water is properly attended to, and the strong alcoholic vapors pass off into the condensing vessel, M, where they are liquefied, and flow out into the receiver, S. When the liquor in the tank, N, appears exhausted, it is no longer returned into the still, but is rejected as useless, and fresh quantities of wine are run in by turning the stopcocks of the pipe, P, and the distillation continued, till the accumulation of tartar and coloring matters renders it necessary to discharge the whole contents, so as to guard against the stills becoming furred.

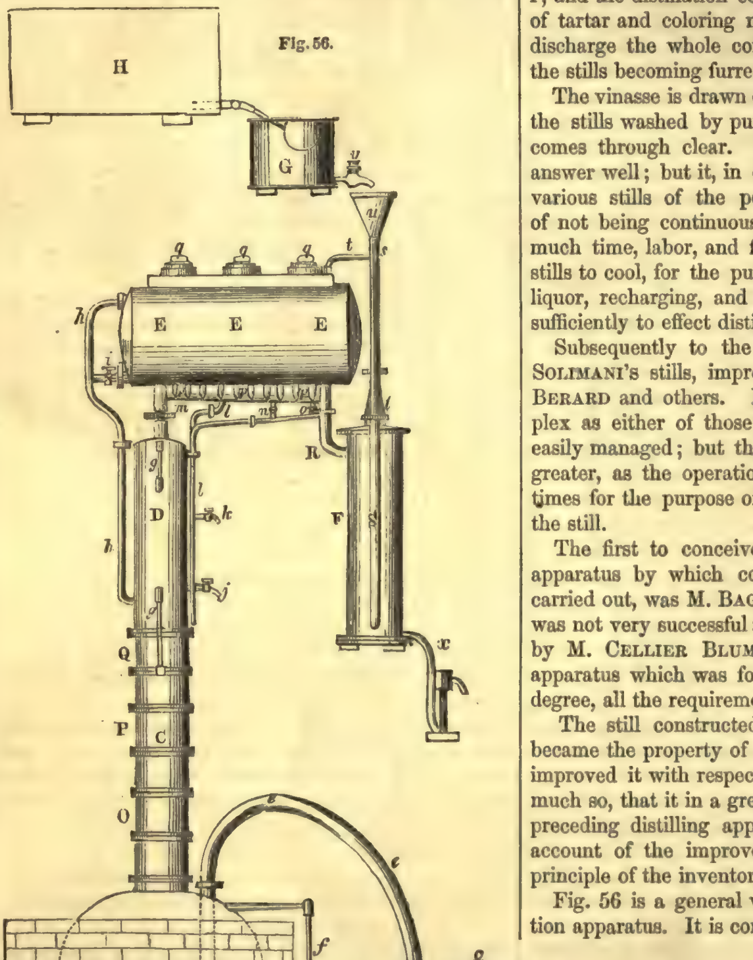


Fig. 56.

The vinasse is drawn off by turning the taps, *r r′*, and the stills washed by pumping water into them till it comes through clear. This apparatus was found to answer well; but it, in common with ADAM'S and the various stills of the period, retained the great evil of not being continuous in its operations, and hence much time, labor, and fuel were lost, by allowing the stills to cool, for the purpose of discharging the spent liquor, recharging, and again raising the temperature sufficiently to effect distillation.

Subsequently to the introduction of ADAM'S and SOLIMANI'S stills, improved ones were announced by BERARD and others. BERARD'S still was not so complex as either of those mentioned, and it was more easily managed; but the loss in fuel was considerably greater, as the operation had to be arrested several times for the purpose of discharging and replenishing the still.

The first to conceive the idea of constructing an apparatus by which continuous distillation might be carried out, was M. BAGLIONI. His attempt, however, was not very successful; but the subject was taken up by M. CELLIER BLUMENTHAL, who constructed an apparatus which was found to possess, in an eminent degree, all the requirements.

The still constructed by BLUMENTHAL afterwards became the property of M. DEROSNE, who very much improved it with respect to continuous distillation; so much so, that it in a great measure superseded all the preceding distilling apparatus. The following is an account of the improved still of DEROSNE, on the principle of the inventor.

Fig. 56 is a general view of the continuous distillation apparatus. It is composed of seven principal parts —namely, the boilers, the distilling column, the rectifying column, the condenser and wine-warmer, the refrigerator, the vat where the wine is contained, and the vessel which determines the flow of wine into the apparatus. Of these, A and B are the boilers, encased in masonry or brickwork. The fire is applied under A, and the extra heat is communicated to B by the flue passing under it in its way to the chimney; C is the column of distillation; D the column of rectification; E E the condenser and wine-heating vessel; F the refrigerator;

G is a vessel that furnishes the wine to the refrigerator—this vessel supplies itself, by means of a stopcock, from the store-vat, H, where the wine to be distilled is kept. The cock of this part is regulated by a floating ball, which closes it when the liquid rises in G. I is a tube of communication, conducting the alcoholic vapors of the rectifying column, D, to the worm in the condenser, or wine-heating vessel.

a is a stopcock, which carries off the spent wine of the boiler, A. When the operation is in progress, this cock is always open, and the exhausted wine flows off continually. *b* is a gage-pipe, which indicates the height of the liquid in the boiler, A; *c*, a safety valve or pipe, to show the pressure on the boiler, A; *d*, a stopcock, which allows the liquid from the boiler, B, to flow into the bottom of the boiler, A; *e e* is a tube that conducts the alcoholic vapors formed in the boiler, A, to the bottom of the boiler, B; the vapor, in passing through B, heats the liquid and condenses in part. *f* is a gage, to show the level of the liquid in the boiler B; *g*, *g*, level gages, indicating the height of the liquid in the compartments of the rectifying column, D; *h*, a tube, conducting the wine of the lower part of the condenser, E, to the topmost beveled plates in the interior of the distilling column; *i* is a stopcock, by which all the heated wine in the wine-heating vessel, or condenser, E, flows into the column, C, when a distillation is coming to a termination; *l l* are tubes, adjusted to the wine-warmer—the one descends as far as the lower compartment of the rectifying column, whence it rises again to the fifth; the other tube descends as far as the third compartment, and rises again above the second compartment. At the point of curvature of each, stopcocks *j* and *k* are fixed, intended to draw off, at will, the small portion of the condensed liquid brought back into the rectifier. *m*, *n*, and *o*, are tubes connected with the inclined pipe, *p p*, at one end, and the pipes, *l*, *l*, at the other. The three communications serve to produce a brandy of more or less strength. If it be required to obtain a stronger spirit, the alcoholic vapor that is condensed in the worm, S, is entirely reconducted to the rectifier, D; and, that this may be attained, it is only required to open the stopcocks, *n* and *o*; a spirit less strong is obtained on closing the stopcock, *o*, and a still weaker product on closing the stopcock, *n*; for the liquid formed in the worm of this cylinder flows off to the refrigerator, F, together with the stronger alcoholic vapor. *p p* is a pipe for receiving the whole of the alcoholic liquid condensed in each of the revolutions of this worm. *q q q* are closed openings in the upper part of the wine-warmer, which admit a person for the purpose of cleaning it. R is a tube conducting the alcoholic vapors not condensed in the wine-warmer to the worm of the refrigerator, F, where they are wholly liquefied; *s*, a tube which supplies the wine from the reservoir, G, to the lower part of the refrigerator, F. *t* is a tube which conducts the wine from the upper part of the refrigerator, F, to the upper part of the wine-warmer, E. *u* is the funnel-opening of the pipe, *s*, conducting the wine from G to the refrigerator; *v*, a stopcock, regulating the flow into the tube, *t*; *x*, a tube conducting the finished spirit from the refrigerator—it is so constructed, as appears in the figure, that an areometer adjusted to it always indicates the strength of the brandy. Having described the apparatus, it will be necessary to say a few words in explanation of the complex parts.

The interior arrangement of the distilling column is represented in Fig. 57. The surface of the liquid descending through this column is greatly increased by flowing in a thin stratum over the several plates successively, and the alcohol it contains eliminated with great facility by the ascending hot vapor. There are three openings, O P Q—Fig. 56—for cleaning the inside. Ten pair of copper plates are enclosed in this cylinder, and placed in such a zig-zag way as to recline downwards alternately, as seen in the section; the liquid, entering at the top, falls over each of the plates in succession, thus making a longer course, and becoming more exposed to the hot vapor.

Fig. 57.

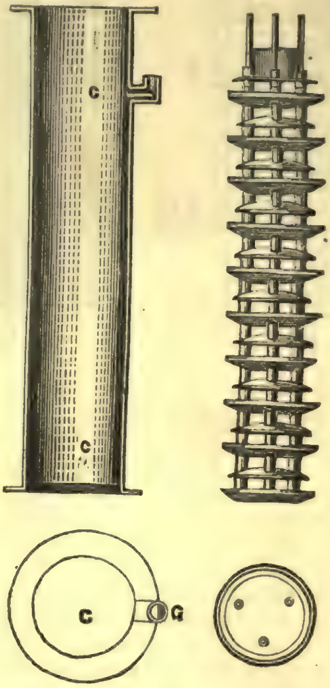


Fig 58 is a sectional, and Fig. 59 an exterior view of the rectifying column. Six inverted vessels occupy the interior, and are so arranged that the alcoholic vapor is forced to traverse a thin layer of liquid in each. The condensed liquid returns to the column, C, and the uncondensed vapor passes onwards to the worm in the first condenser by the pipe, I.

In these figures the position of the pipes, L L, will be better understood; in the front view one is represented descending to the lower and rising again to the third vessel, and the other coming to the third and mounting again to the second, and the sectional figure shows the communication of those pipes with the interior of the cylinder. G G are cases for the glass gages; and the sketches at foot are bird-eye views of the position of the respective tubes, here indicated by the dark spots, and the letters, H, M, K, J, and L.

Fig. 58.

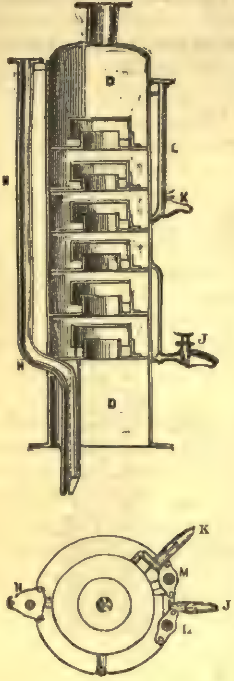
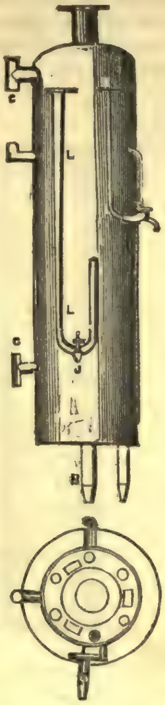


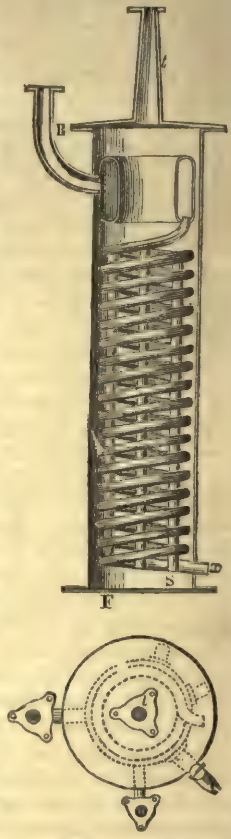
Fig. 59.



Figs. 60, 61, and 62 are details of the condenser, E, the first being an end view, the second a longitudinal, and the third a transverse section at x', Fig. 61.

At each revolution of the worm, in Fig. 61, it communicates with the canal, *p p*, by a short connecting pipe. The wine enters from the pipe, *t*, shewn in the upper part of Fig. 56, and percolates small holes, as seen at *y y* in Fig. 61, over the worm, which it thereby cools sufficiently to condense most of the aqueous part of the vapor passing through it. Fig. 63 shows the arrangement in the refrigerator, S; and the cut appended, a bird-eye view of the top of this column. In these figures, the same letters indicate the same parts as in the general view, Fig. 56.

Fig. 63.



Referring, therefore, to Fig. 56, in connection with the parts shown in detail,—when operations are to commence, the boiler, A, is filled with wine through K, till within two or three inches of the top, as indicated by the gage, *b*; the fire is lighted, and the stopcock, *v*, opened, and the wine allowed to flow into the refrigerator, F, thence into the condenser, E; and when this vessel is filled, the liquid flows through the overflow pipe, *h*, into the distilling column, C, and ultimately to the boiler, B, until it rises to within five or six inches of the top of the gage pipe, *f*, when the cock, *v*, is closed. As soon as the liquid in A boils, alcoholic vapor escapes by the pipe, *e*, into the bottom of the boiler, B, where it is at first condensed, and thereby the liquor in this vessel becomes richer in spirit. Shortly, the liquor in B, in consequence of heat it derives from the traversing vapor, and its being richer in alcohol, begins to boil; part of the vapor rising through the distilling column and rectifier is condensed, while the uncondensed portion passes into the condenser through the pipe, I. When the liquid in the condenser becomes so hot that the hand cannot rest in contact with the outer case, the stopcocks, *a*, *d*, and *v*, are opened, and the wine allowed to flow till it reaches the boilers, B and A. As it descends through the distilling column, it is divested of the greater part of its alcohol by the ascending vapor; during its stay in the boiler, B, almost all the remaining quantity is removed, and the very last traces are separated in the first boiler, so that

Fig. 60.

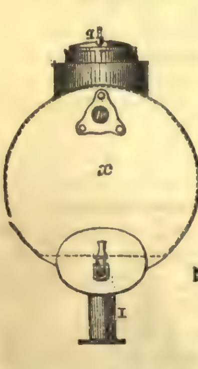


Fig. 61.

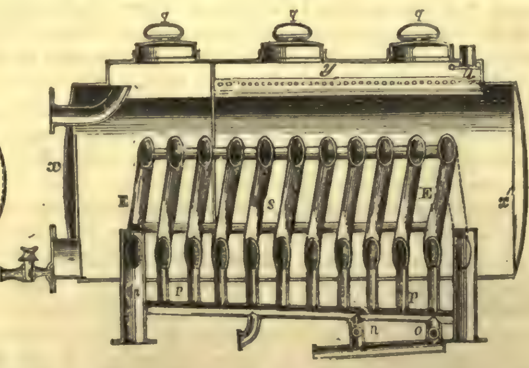
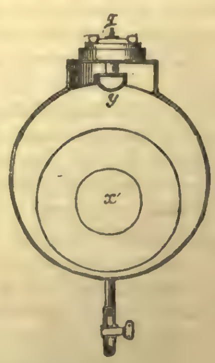


Fig. 62.



it is completely exhausted as it flows off by the waste stopcock, *a*.

It is found, however, that the charge entering into the first boiler from B, if allowed to run off at the full bore of the discharge-cock attached to boiler A, would retain small quantities of alcohol. If the alcoholic liquid remained always in a higher stratum in the boiler, then the tap, *d*, might be left open; but, in consequence of the boiling of the liquid, no such division can be expected. On this account, therefore, it is absolutely necessary to shut the discharge-cock of boiler A, for a longer or shorter time, while the liquid is in a state of ebullition, and to slacken the fire while the spent liquor is drawn off from the boiler.

Another still was contrived to carry out the principle of uninterrupted distillation by M. **St. Marc**, a veterinary surgeon attached to the personal staff of Bonaparte. After the battle of Waterloo, **St. Marc** turned distiller in France, and, about the year 1823, he removed to England. Here he, and a few others, formed a company for the fabrication of brandy from potatoes, and erected large works near London; the project failed, after three years' operation on a very extensive scale, leaving the speculators minus some forty or fifty thousand pounds.

St. Marc, however, was not idle during the time the works were extant, for, by attention to his views on continuous distillation, he effected many valuable improvements in the form of his still. He completed this article in 1827, and obtained a patent for the United Kingdom; he then disposed of it to some London gentlemen, and returned with the proceeds to his native country.

This still came into great request among the principal distillers of London, Bristol, and other chief towns, where it had been reputed to work with great satisfaction. For the distillation of wash, however, it ranks far behind **Coffey's**. It is said, that at the establishment of Messrs. **Nicholson** at Clerkenwell, one of these stills produced one thousand gallons of gin hourly, the cleansing and flavoring processes proceeding at the same time. It was in great demand, also, for the distillation of rum in the West Indies, and several other English colonies, as, by its use, considerable outlay in fuel, puncheons, freight, and shipping charges were dispensed with.

Figs. 64 and 65 are sectional and front engravings of the still. It consists of seven coppers, placed one above the other, and numbered in the section, 1, 2, 3, 4, 5, 6, 7, of which six contain the wash or liquor to be distilled, and the seventh or upper one, water. The coppers, which are held together by flanges and bolts, communicate with each other by the double tubes, A A, through which the vapor ascends, and also by the pipes, B B, by means of which the wash descends from one copper to another in succession, beginning with the uppermost but one, N 6, into which it is introduced by a pipe and tap, C, from the wash-charger, D. The lowest or first copper, which constitutes the body of the still, and receives the heat of the fire, does not differ from the ordinary boilers, but the second and third coppers each contain four of the double tubes, A,

Fig. 64.

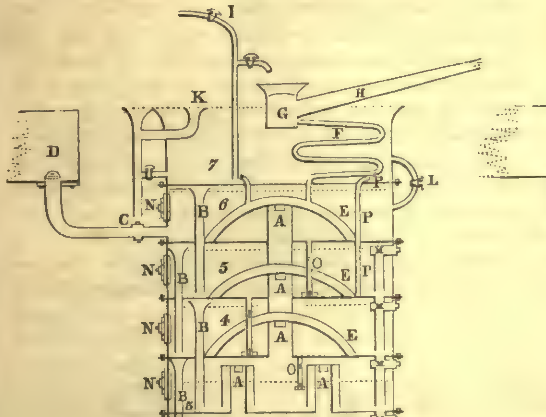
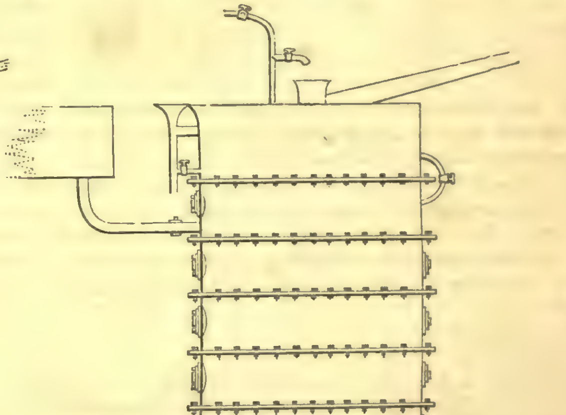


Fig. 65.



and two of the pipes, B. The fourth, fifth, and sixth coppers have likewise the pipes, B, but have only one double pipe, A, in each, placed under hemispherical domes, E E E, constructed upon, and tightly flanged and bolted to the coppers that have just been mentioned. Six spiral tubes, or vertical worms, F, of which only one appears in the engraving, conduct the vapor from the upper dome through the water in the top division; these communicate with the chamber, G, capped by a small dome and pan, which is kept replenished with cold water, and the portion of vapor remaining uncondensed passes out to the common condensing worm, by the large pipe, H. I shows a pipe and stopcocks for conveying water to the top copper, No. 7, and chamber, G, and any waste water that may be used for scalding or cleaning the backs is carried off by the pipe, K, which is furnished with a branch pipe and stopcock. Water is conducted from the upper copper through the pipe and stopcock, L, to the several lower compartments into which it is introduced by means of the stopcock, M, appended to each; the water is used for bringing down the wash at the close of a back, as well as for cleaning the coppers. A man-hole, N, is furnished opposite to the pipe and stopcocks, M, to admit of their being thoroughly cleansed, and also to make repairs.

Having described the apparatus, it only remains to give a brief account of the operation. In the words of MOREWOOD:—

The first three coppers—of which the second and third only are intersected with double pipes—distil almost at the same time; the lowest, being that submitted to the action of the fire, operates on the others by the discharge of its vapor, which, ascending by means of the pipes, passes into the wash, and is there condensed, infusing its caloric into that liquid, which is thereby quickly brought to the boiling point. The uncondensed portion of vapor from the second compartment passes into the third with similar effect. The new vapor, necessarily stronger than the first, ascends into the fourth section, where it is received under a semispherical dome, which prevents it communicating directly with the cold wash contained in that copper. In this place the more aqueous portion of the vapor is condensed, and during this transition it yields its latent heat to the wash which surrounds the dome, bringing it to a higher temperature. The most volatile or spiritous portion, which passes into the fifth section, experiences the same change as the vapor in the fourth dome, and so on to the uppermost — the alcoholic vapor becoming stronger as it traverses every succeeding dome. The condensed portion in each dome returns through the coppers to the third chamber, and meeting with the ascending hotter vapors, they are partially redistilled in their progress. In the third copper a second distillation commences, giving off anew its alcohol.

To explain why the watery vapor is forced to return to the third copper, and is there found totally separated from the alcohol, it is sufficient to state, that water does not boil under a heat of 212° Fahr., while alcohol boils at 173°. When, therefore, the watery and alcoholic vapors rise, and are successively received in one or more atmospheres of from 200° or 190° to 174°, the aqueous vapor becomes separated from the alcoholic, and is condensed, and the latter alone passes out to the worm, and thence to the receiver at the desired strength.

From the foregoing particulars, it is evident that a large portion of the spirit is distilled by vapor or steam, and is, consequently, more pure than that obtained by the ordinary apparatus. If, therefore, all the bad flavor arises from long and violent exposure of the wash to the action of the fire, this process, as well as those already described, is calculated to obviate entirely that injurious effect, and to yield a spirit wholly divested of any empyreuma. One distillation only is effected by the fire; this is immediately succeeded by two vapor or steam distillations, and, subsequently, by four purifying consecutive processes, which divest the spirit of all impurities, and it comes over, at one operation, of the strength of 35 or 40 per cent. over proof, by SYKES' hydrometer.

A still of seven compartments, such as described, will produce spirit no stronger than 35 or 40 per cent. above proof; but, by increasing the number of coppers or sections, a much stronger liquor might be obtained by a single operation.

To ascertain the precise time for charging, after the exhaustion of the wash in the lower copper, it is only necessary to open what is called the proof tap placed in its side; and if the vapor issuing from it will not ignite on the application of a candle, it is evident a fresh charge is wanting. The discharge of the spent wash from the lowest vessel, the supply from the next copper to replace it, and the opening of the tap in the pipe, communicating between the charger and the top of the still to admit more wash, are all the work of about a minute, during which distillation never ceases.

The advantages of this apparatus are numerous, but may be briefly stated to consist in the saving of about two-thirds of the fuel usually consumed; an increased produce, by economizing what is lost by evaporation in the three compartments, with their pumpings, *et cetera*, in the ordinary system; a considerable saving of labor, there being but one furnace, and one tail-pipe, instead of three or sometimes four; to which may be added, the advantage of dispensing with low wines and faints' receivers and chargers, together with their connections and pumps, and the power required to put them in operation.

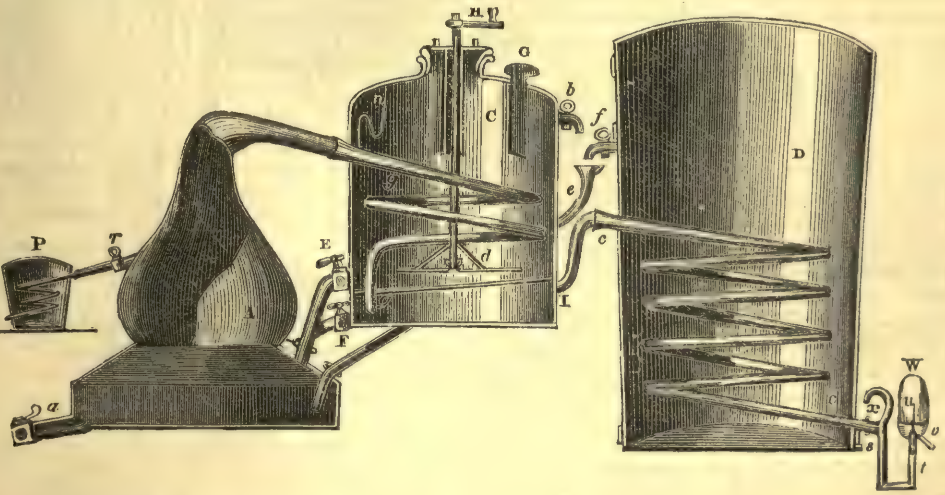
A safe of a superior nature has been constructed by Mr. SHARPE, one of the patentees. It is attached to the end of the worm, and holds a large glass cylinder, in which a thermometer is suspended; at each side of this cylinder are two smaller ones, in which are placed hydrometers, one for ascertaining the strength when *above*, and the other when *below* proof. The safe is so ingeniously contrived, as to enable the distiller to see the strength and color of the spirits, and also to take a sample, which, however, is registered against him upon a dial, and no spirit can be surreptitiously obtained, while it serves to prevent fraud both on the proprietor and the revenue.

The Germans employed, and still use on a small scale, an apparatus for the distillation of the fermented extract of malt, similar to Fig. 66, and which bears the name of DORN'S still.

The principal parts are the body of the still, A, the wort-warming vessel, C, and the condenser, D. The still is furnished with a discharging-cock, *a*, and a small pipe with stopcock, *r*, is inserted in the head, which pipe is connected with the end of a small worm in the tub, P. C is an iron or copper vessel, furnished with a double bottom, the one twelve inches above the other. In the upper part of this vessel are contained a few coils of worm, *g g*, the lower end of which passes downwards through the first bottom to within one or two inches of the other. An opening at the top of the preparer receives an agitator, H, which may be turned by the hand; a cross bar, *d*, at the end of this upright rod, skims the interior bottom of any sedimentary matter which may deposit on it. The opening, G, serves to charge the vessel with liquor; E and F are communications between both compartments of the vessel, C, and the body of the still, for the purpose of supplying it with the liquor contained in both these parts for distillation; *b* is an overflow-pipe and stopcock, by which it is ascertained when C is replenished. A pipe, I, issues from the far end of the lower part of the vessel, C, and is connected with the second worm, *c c*, in the large worm-tub, D. Another pipe, *e*, enters the preparer for the purpose of cleaning it with water at the termination of the distillation; the water is run into the boiler of the still, and drawn off at the discharge-cock, *a*. A pipe from an adjacent cistern, or reservoir, supplies the large tub, D, with cold water, and from this tub water is supplied to the pipe, *e*, through the stopcock, *f*.

An apparatus is furnished at the end of the worm, as it issues from the tub, in order that the flow of the liquor may be observed, and its strength noted at the same time. It consists of a tube, bent at right angles, as at *s t*, the upper part of which terminates in a curve, *x*, through which the air of the worm is expelled. The arm, *t*, is terminated in a basin, holding an inverted glass jar, W, in which a hydrometer, *u*, is placed, and floating in the spirit, in order to tell the proper strength. The pipe, *v*, carries off the finished spirit into the tank, where it is collected.

Fig. 66.

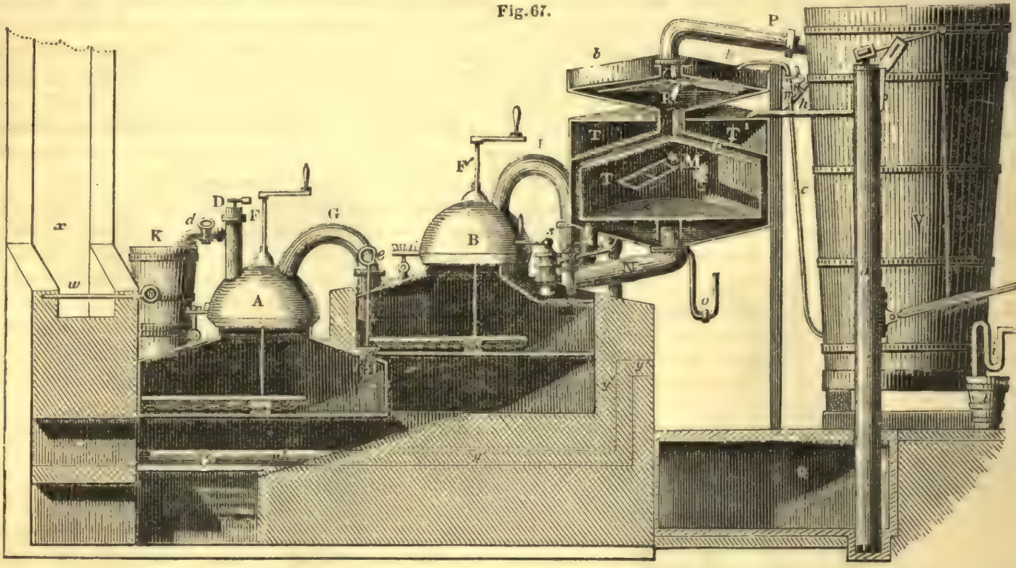


Operations are commenced by filling the preparer, C, with liquor, through the pipe, G, till it flows out at the stopcock, *b*, after which the cock, E, is opened till the still is filled to the overflow-pipe, which regulates the amount of liquor to be introduced, but which is not seen in the section. When this happens, the cock, E, is closed, and the vessel, C, filled to the proper height, then G is closed by a screwed cap or plug, and the furnace lighted under A. As the alcoholic vapor rises, it is partly condensed in the few coils of worm in the vessel, C, the liquid falling down to the bottom compartment; and the liquor in the vessel is heated by the latent heat of the vapor. As the liquor collects in the bottom part of the vessel, the remainder of the uncondensed portion of vapor gurgles through this liquid, which further deprives it of aqueous vapor; the portion uncondensed issues through the connecting-pipe, I, to the large worm in the condenser, where it becomes wholly liquefied; the excess of liquid in the lower part is allowed to flow into the still by the pipe, F. The charge in the still, when the whole of the alcohol has been expelled, is emptied through the discharging-cock, *a*, a fresh supply of the heated liquor in C introduced as before, and a second operation commenced—taking the precaution to slacken the fire while this part of the work is going on. The small condenser attached to the boiler or still, is to test whether the charge is wholly exhausted, and the small pipe, *n*, permits the escape of the air in the worm and lower part of the compartment in C.

Since the introduction of a better apparatus, DORN'S is seldom used by the large distillers; it is, however, met with in small establishments, and where brandy is rectified.

The apparatus generally employed throughout Germany for the distillation of fermented worts, *et cetera*, is that represented in section in Fig. 67, and known as PISTORIUS', from his improvements and additions. In this figure, A and B are two boilers, connected by the pipe, G, which conducts the vapors formed in A into B. These boilers are each furnished with an agitating chain apparatus, F, F′. C is the fire-grate under the boiler, A, and the excess of heat is rendered available towards heating the other boiler by the flue winding under it before entering the chimney, *x*. D is a kind of safety-valve attached to the first boiler, and is furnished with a stopcocked pipe, *d*, that communicates with a small worm in the condensing tub, K; this contrivance is intended to test when the charge in the boiler is divested of the whole of the alcohol. The boiler, A, is charged from the contents of the second boiler, B, by means of a connecting-pipe, E, having a valve appended, the handle of which is seen at *e*. A large pipe, L, issues from the head of the boiler, B, and is connected with another pipe, N, of a larger calibre, having another smaller pipe, S, connected with the other end. The alcoholic vapor from the two boilers, A and B, passes through these tubes into the rectifying vessel, M, supplied with a second bottom, from which descends a vertical cylinder over the pipe, S, nearly to the exterior bottom. *r r r r* indicate the course of the vapor through the vessel, M; this passage is made of sheets of copper of nearly the same breadth as the vessel, soldered to an end plate of a few inches in breadth. The remaining parts of the vessel, noted by T T T, are charged with wash for the purpose of heating it before distillation. The spiritous vapor, on passing through this rectifying vessel, loses a great portion of water by condensation; but the chief quantity is separated in the double conical space, R, which is surmounted by a vessel of the same form, *b b*, filled with cold water from the large condensing tub. The pipe, P, conducts the uncondensed alcoholic vapor to the large condensing worm in the tub, V. The liquid formed in the passage *r r r* and R, collects at the bottom of the vessel, M, so that the vapor entering by the pipe, S, has to pass through it. When it accumulates, it is run into the boiler, B, by a connecting-pipe, *x′*, which is closed and opened at pleasure by means of the valve, *y*. *s* is the valve attached to the pipe which conveys the fermented wash from the compartments, T T T, in the vessel, M, to the boiler, B. The pipe, *c*, supplies the conical condensing vessel, *b b*, with cold water, and the pump, *a*, raises the fermented wash from the tank, Q, beneath, and discharges it into the vessel, M, by the pipe, *h*. When the space in the interior of M requires cleaning, water from the condensing tun is run in through the pipe, *m*, by turning the stopcock. *o* is a siphon tube, through which the air of the apparatus is expelled, when the fire is lighted under the boiler, A; it is closed by the stopcock when the alcoholic vapor reaches thus far.

Fig. 67.



The waste caloric from the furnace is made to warm the water employed in mashing the grain, by a pipe, *y′ y′*, leading from the fire, that carries off the heated vapor for that purpose. The spirit is received in a peculiar manner from the lower end of the worm, as will be explained after describing the mode of operation.

The fermented liquor to be distilled is pumped up into compartments, T T T, in the case, M; the valve, *s*, of the pipe connecting the space, T, with the boiler, B, is then opened, and the wash introduced into this boiler, whence it is allowed to flow into the first boiler by opening the valve, *e*, of the connecting-pipe, E. This valve is left open till the liquid rises to the proper indication, as shown by a gage in front, but not seen in the figure; *e* is then closed, and all the other taps, leaving a free course for the vapors to flow off to the condenser. When this is done the fire is lighted. After a short interval, the liquor in A begins to boil, and the vapor passes over into B, whose contents are also raised to ebullition, which takes place at a lower degree in consequence of the quantity of alcohol it receives from the preceding.

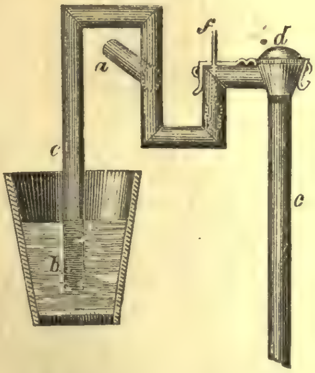
The alcoholic vapor from B passes over by L through the pipe, N, into the rectifying spaces, *r r r r*, where the excess of the watery vapor is condensed, and falls to the bottom of M. This liquid being the product of the former two distillations is very rich in alcohol;

and when it accumulates sufficiently to cover the end of the pipe, S, the hot steam from the boilers bubbling through it disengages a vapor surcharged with alcohol; thus a third distillation is effected. When the liquor is present in too large a quantity, the valve, *y*, is occasionally opened to run it into B. The uncondensed portions rise and pass from the conical-shaped condenser, R, into the large condensing worm in the vessel, V, where they are completely condensed, and flow out at the lower end of the worm into the vessel, or receiver.

If, on turning the vapor into the small worm in the vessel, K, and collecting the condensed portion, it be found that in the contents of this boiler no more alcohol is retained, the spent liquid is drawn off by the discharge-pipe, a fresh charge admitted from the boiler, B, and this in turn refilled from the compartment in the rectifying vessel, M. During the discharging of the liquid in boiler, A, and its refilling, the fire is slackened, by inserting the damper-plate, *w*, into the flue to cut off the draught.

The three distillations which here take place give a very strong spiritous liquor, and of a very good quality. At the end of the great worm is a water-tap, or a similar apparatus to that shown in Fig. 68. In this diagram, the end of the worm issuing from the great condensing tub is seen at *a*. *c c* is a zig-zag pipe, one end of which is immersed in a bucket of water. In the upright part of the discharging-pipe is an alcoholometer, *f*, by which the strength of the distilled product is ascertained, and *d* is a watch-glass covering the funnel-opening in the larger end of the tube, used for the purpose of seeing the bulk of the stream of liquid which flows through the worm. By this contrivance the air is prevented entering the worm, and therefore no acetic acid is produced.

Fig. 68.



The distillatory apparatus of ALÈGRE is described in the succeeding Figs. 69 and 70. The operation in this, as will be seen, is carried on by means of the steam generated in a boiler which forms one part of the whole; and this steam, traversing the liquid to be distilled, causes the heat of the latter to rise to the boiling point, by which the spiritous vapor is expelled, and subsequently, in its route through the apparatus, rectified and condensed, as will be demonstrated after explaining the figures, to which the reader's attention is now invited.

Fig. 69 is an elevation of this distilling apparatus on the furnace side, and Fig. 70 a section made parallel to the visible part of Fig. 69. In these figures are the following parts; namely, A, the brickwork enclosing the fire, and part of the lower boiler; B, the door of the furnace; E, the lower boiler, part of which is encased in the brickwork. F is a pipe issuing from the bottom of boiler, E, furnished with a stopcock, and serving to discharge the liquid that remains after distillation, or whenever required. *g* is a pipe and stopcock, by which the proper height of liquid to be introduced into the boiler is regulated, as shown by the dotted line, *h h*, in the section. I is a tubular opening, which facilitates the cleaning of the boiler when necessary; this opening is closed by a slide plate firmly fixed in its place by bolts, or it may be secured by a screw-cap. *k* is a pipe and stopcock for ascertaining when all the alcohol has been eliminated from the liquid in the boiler, E. L is another boiler placed upon E, and which is emptied when requisite by the discharging-pipe and stopcock, M. Both these boilers are connected by the pipe, *n*, to which a stopcock is affixed. *o* is an overflow-pipe and stopcock, serving to regulate the height to which the liquor should rise in the boiler, L, as is shown in the sectional figure by the dotted line, *p*. Q is the stout plate or division between the boilers, E and L; in the middle of this bottom is an opening, on which is fixed the pipe, *r*; this pipe is open at both ends, and passes up through the liquid in the boiler, L, towards its neck; *s* is a hollow cylinder, which is inverted upon the pipe, *r*, and having its closed end uppermost. The open end rests on three small supports, fixed equidistant from the pipe, *r*, and elevated one inch above the bottom of the boiler, L; *t* is a third hollow cylinder, issuing from the bottom of the boiler, L, and rising perpendicularly till it terminates in an open end, about one inch above the closed end of the hollow cylinder, *s*, which it surrounds; *u* is a fourth hollow cylinder, placed in exactly the same position as the cylinder, *t*, and enveloping all the foregoing; the closed end being topmost, and the lower open extremity resting upon three elevations of one inch in height, and equidistant from the cylinder, *t*. A distance of half an inch is left free between its closed end and the orifice of the cylinder, *t*. *v* is a fifth hollow cylinder, which encloses the whole of the others. Its lower extremity is fixed in the bottom, Q, of the boiler, L, and its upper extremity is attached to the closed end of the cylinder, *u*. In the arrangement of these cylinders, they open alternately at the top and bottom, and by this means a passage is made for the vapor over each cylinder in succession.

x x are tubes issuing from the top of the cylinder, *v*, at an angle of about 45°, and descending to within two inches of the bottom of the boiler, L; these tubes are open at both ends, and serve as valves to close the cylinders, *v* and *u*. Three of these tubes are provided, and are fixed at the angular points of an equilateral triangle, supposed to be inscribed in the circular plane of the closed end of the cylinder, *v*; but of these only two appear, the third being in the segment of the figure which is removed.

y is a safety tube for the purpose of preventing the influx of the liquid in the boiler, L, through the open pipes, *x x*, into the cylindrical spaces in the interior of the enveloping cylinder, *v*. The upper extremity, which is funnel-shaped, is in contact with the atmosphere, and the other is in communication with the spaces in the interior of the cylinders, *v* and *u*, by passing through the closed end of the cylinder, *v*. This tube is curved, so that, at or near its middle, it dips into the liquid in the boiler. In the part ascending from this curvature to the top of the cylinder, *v*, is a bulb or enlarged portion, *z*, capable of holding about a gallon of water introduced at the funnel-opening, *y; a* is a stopcock, which enables the operator to know the state of the distillation in the boiler, L, and is similar to *k* in boiler, E.

c is a large tubular opening in the shoulder of the boiler, L, similar to I in the lower boiler, and affording a means by which any accumulated dirt or other matters on the bottom of the boiler is withdrawn. It is closed in the same way as I.

C is a circular basin placed upon the neck of the boiler, L, forming a refrigerator; *d*, a pipe and stopcock, which conveys heated water from the basin, C, into the lower boiler; *e* is a vase of an elliptical form, joined to the neck of the upper boiler by a bracket and rivets, as seen at *f; gg* are two tubes descending from the hollow cylindrical vessels enclosed in *v*, into two small vases, or circular vessels. By these pipes the phlegm condensed in the passage of the vapor over the cylinders, is returned to the lower boiler, E; the small vessels prevent any vapor passing up by these tubes—they act as a water stopcock; *h′* is a tube having two stopcocks, and branching a little below the upper stopcock; by this tube the phlegm condensed in the oval vase, *e*, is conducted at will into either of the boilers by opening the proper stopcock. *i* is a tube, rising vertically through the vase, *e*, to within one inch of the upper part of the vessel. It is closed at the top by a plate and a hollow cylinder, *k′*, whose closed end is uppermost, and rests upon *i*. The open end of the cylinder, *k′*, terminates about one inch above the bottom of the vase, *e*. The upper part of the pipe, *i*, is pierced with a number of small holes, through which the vapor passes into the vase; *l* is a tubular opening in the elliptical vase, *e*, by which it is cleaned; this opening is closed by a wooden plug; *m* is a circular basin, containing cold water, placed upon the vase, *e*, and acting as a refrigerator, and which discharges its hot water by the pipe and stopcock, *n′*.

Fig. 69.

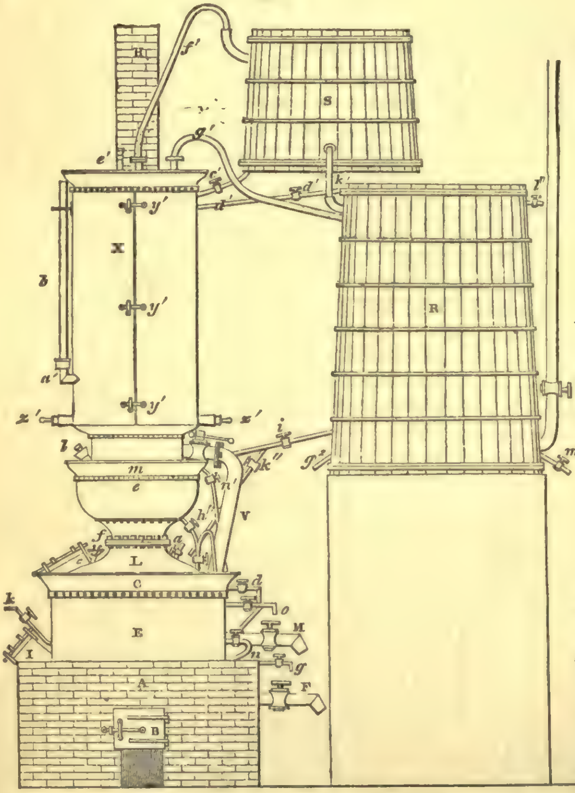
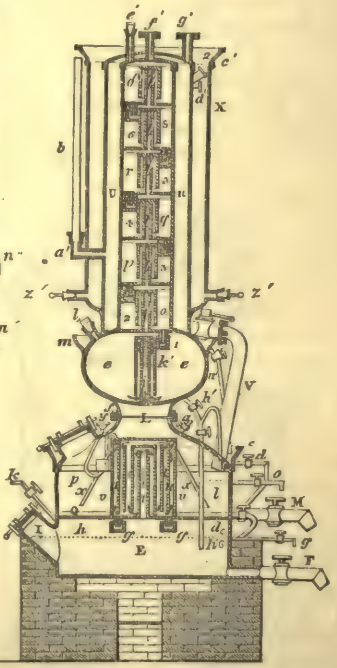


Fig. 70.



o p q r s o′ are six compartments, or diaphragm rectifiers, placed one above the other, forming by their union one cylindrical column; these diaphragms communicate with one another by means of six small tubes, *l′ l′ l′ l′ l′ l′*, placed in their centres. The tubes are arranged similarly to the tube, *i*, in the vase, *e*, the upper part of each tube being closed, and enveloped by an inverted cylinder in the form of a hat, descending to within an inch of the bottom of each diaphragm. The *l′* tubes are perforated in the upper part, to allow the vapor to pass off, and a small pipe descends alternately at either side of the column from each compartment into a small trough or dish, 1, 2, 3, 4, 5, 6, similar to those seen at *g g*, in the lower boiler, E. By these pipes the phlegm condensed in each compartment descends into that which is immediately beneath it, until it finally comes into the elliptical vase, *e*, and thence, by the double-stopcocked pipe, h', it is conducted into either of the boilers, at the pleasure of the operator. Hence the condensed phlegm descending, offers no obstruction to the ascending alcoholic vapor. A long vertical hollow cylinder, U, envelopes the six compartments, $o\,p\,q\,r\,s\,o'$, but a space of six inches intervenes. Water is introduced into this space, and thus the cylinder, U, acts as a refrigerator to the interior column.

The hot water is discharged from the refrigerator by the large pipe and stopcock, V, into the upper boiler, whenever required. X is a cylinder reposing upon a projecting edge attached to the cylinder, U, and which serves as its base; it is made to open and shut by the latchkeys, $y'\,y'\,y'$. The space between this envelope and the cylinder, U, is destined to receive the grain which has germinated—malt—in order to torrefy it previous to grinding. The cover of this envelope is perforated with small holes, which give passage to the vapor evolved from the torrefying grain. $z'\,z'$ are two apertures made in the base of the envelope, X, by which the grain is withdrawn when properly dried. a' is a tube communicating with the interior of the refrigerating cylinder, U, bent upwards at right angles; at a short distance above this angle the tube is enlarged, forming a receptacle for the glass tube, *b*, serving as a gage to show the height of water in the refrigerator. c', a tube with stopcock, by which the fermented liquid is conveyed into the refrigerator when one wishes to carry on the distillation by the assistance of the cylinder, U, in conjunction with the boilers; however, whether the liquid to be distilled be wine or wash, it is invariably heated here, so that it may be afterwards let down at nearly a boiling temperature into the boilers by the large tube and stopcock, V, and the smaller one, h'. d' is a pipe and stopcock, by which wine may be introduced in the same way as the wash from grain by the pipe, c', when that liquid has been employed in the course of operation. e' is a tube by which water is allowed to enter the rectifier, composed of the six compartments, $o\,p\,q\,r\,s\,o'$, containing the cylindrical enclosures, $l'\,l'\,l'\,l'\,l'\,l'$, for the purpose of cleaning it. f' is a tube, which conducts the rectified spiritous vapor from the summit of the column to the condensing worm in the superior condenser, S. g' is a small tube, conducting the spiritous vapor arising from the liquid in the refrigerator, U, into a small worm placed in the large condensing tun, R, collaterally with the large one. The chimney has a damper to regulate the draught from the furnace, B, which must be diminished during the charging of the apparatus.

Manner of conducting the Distillation.—When the apparatus is prepared, as seen in the figure, all the stopcocks are shut, excepting the overflow-pipes, *o* and *g*, which are left open.

The commencement of the operation is the filling of the large condensing vessel, R, with water, after which, the superior large tub, S, is filled with *wash* liquor, or wine, as the case may be. This tub contains a condensing worm, wherein the vapor arising through f' is partly condensed, and which is connected to the large worm in the principal condenser, R, as seen in Fig. 69, by the pipe, k'. After S has been replenished with liquor, the lower boiler, E, is filled through the tubular opening, I, with water, then the fire lighted, and the distillation of the water proceeded with, till the liquor in the vessel, S, acquires a temperature of about 100° Fahr. As soon as the steam from the boiling water ascends to the upper boiler, the stopcock of the tube, c', connecting the vessel, S, and the refrigerating space inside the cylinder, U, is opened, and the liquid allowed to flow in until the forementioned temperature is communicated to the remaining liquor in the vessel. When this happens, the cock of c' is closed, and the vessel, S, replenished with more of the liquid. Both the stopcocks of the pipe, h', are next opened, in order that the water condensed in the diaphragms of the rectifying column, as well as in the elliptical vase, *e*, may pass into the boilers; the stopcocks, *i*, k'', are at this time likewise opened to fill the refrigerating circular basins, C and *m*, attached to the upper boiler and vase, *e*. When these are full the cocks are closed, and the fire slackened by throwing on some moist small coal or wood, and inserting the damper. The object of the distillation of the water is to wash the interior of the apparatus, as well as to heat the liquor in the cylinder, U, and in the vessel, S. The stopcocks of the pipes, F, *g*, *n*, are opened in order that the water contained in both boilers, as well as in the elliptical vase, may flow out by F. During the escape of the water, the plate closing the tubular pipe, I, is withdrawn, and a besom, or mop, introduced to clean the bottom of the boiler, and force out the sedimentary matter. When the apparatus is newly erected, this distillation of water is necessary to purify the interior from rosin and other matters proceeding from the soldering, *et cetera*; but in other cases it is not requisite, unless when impurities collect in the boilers or rectifying diaphragms, or when the distillation has been suspended for some days, or after repairs; for when the distillation is carried on uninterruptedly, there is no occasion for such washing of the boilers. It is customary to fill the whole apparatus with water when not required for use, to prevent the formation of any acid which would act on the various boilers and other parts of the whole still; the water is drawn off when operations are on the point of recommencing.

The boilers being empty, the stopcocks F and *n* are closed, and the lower boiler filled with water, until it flows out by the pipe, *g*, which is at this time closed, as well as the opening, I, and the stopcocks in tube, h'. The fire is then hastened by withdrawing the damper; and during the time the liquid in the lower boiler is rising to 212°, the stopcocks of the pipe, V, and of the overflow pipe, *o*, are opened, and the heated alcoholic liquid in the refrigerating cylinder, U, admitted, until the boiler, L, is filled, as is indicated by the liquor flowing out through *o*. These tubes are then closed, and the tube, *c′*, opened to refill the cylinder, U, with the spiritous liquor from the vessel, S, to the proper height, as indicated by the glass gage pipe, *b′*, after which the cock of the pipe, *c′*, is shut. It is particularly necessary that the water in the large condensing vessel, R, should be thoroughly cold. This is effected by opening the stopcocks, *l″* and *n″*. By turning the stopcock, *n″*, the cold water from the reservoir, which should be erected at an elevation, and convenient to the place for the use of the apparatus, flows into the lower part of R, and the hot water is discharged through the pipe, *l″*, at the same time, by the influx of cold water beneath. Matters being thus in readiness, the vessels are charged, and while doing so the fire is briskly urged; the water of the lower boiler soon reaches ebullition, and the liberated steam, coming in contact with the bottom, Q, of the upper boiler, heats the spiritous liquor which it contains. As the steam is generated in greater abundance, it rises through the cylindrical pipe, *r*, and thence descends and ascends alternately in its course over the other successive cylinders, till it escapes by the open ends of the three diverging pipes, *x x x*, immersed in the liquid contained in the upper boiler. During this complicated course of the steam, it imparts its caloric to the surrounding liquid in the boiler, L, the content of which is readily raised to ebullition. By this means alcoholic vapor is evolved through the pipe, *i*, and after traversing the elliptical vase, the uncondensed portions ascend into the six diaphragms, *o p q r s o′*, in the rectifying column, by means of the communications, *l′ l′ l′ l′ l′ l′*. Here the rectification is principally carried on; the more aqueous portion of the vapor is condensed in each ascending compartment till it reaches the top of the column; from which it is carried off by the pipe, *f′*, into the coiled portion of the large worm, deposited in the vessel, S, where it is perfectly condensed in its course through this and the other worm in the large condenser, R, and flows in a fine stream into the appropriate backs, or spirit vats, placed below the protruding end of the worm at *m′*. The phlegm in each compartment of the steam rectifier returns by the small pipes, 6, 5, 4, 3, 2, 1, till it descends into the elliptical vase, *e*, and thence through the pipe, *h′*, into the boiler, L. As the distillation advances, larger quantities of vapor rise from the heated liquor, both in the boiler and oval vessel, *e*, as well as in the lower compartments of the rectifying column, and the condensed water from it is always descending while the distillation of the alcoholic liquor continues to afford alcoholic vapor. This is known by opening the test-cock, *a*, and applying a light to the vapor; if it inflames, it is a proof that there is still some alcohol in the liquid in the boiler, and if it does not ignite, the whole of the spirit has been eliminated; then the firing is finished, and another charge begun. The distillation of the first charge requires a period of three hours, on account of the boiler being filled with cold water; but in each succeeding operation, only two hours are required, as all the parts of the apparatus, with the water in the lower boiler, are hot.

After the whole of the alcohol has been expelled, the boiler, L, is emptied and thoroughly cleansed. This is effected by opening the tubular pipe, *c*, and the stopcocks, M and *o*, to allow the spent liquor to flow out; during this time a broom, or mop, is introduced through *c*, to detach all impurities, and force them out with the liquid through the discharging-cock, M. After the interior of the boiler has been thoroughly purified, the opening, *c*, and the stopcock, M, are shut, and the cock, V, opened, in order to allow the heated liquor from the refrigerating compartment in U, to flow in to refill the boiler. When the liquid has risen to the level of the pipe, *o*, the cock, V, is shut, and the communication between the refrigerating cylinder and the vessel, S, containing the liquid to be distilled, is opened by turning the stopcock, *c′*, and the cylinder refilled to the proper height, as indicated by the gage pipe, *b′*. The connecting-pipe between the vase, *e*, and the under boiler, is opened by turning the cock, *h′*, and closing the lower one with which this pipe is supplied, in order that the phlegm collected in the vase during the distillation of the preceding charge may flow into the lower boiler, whose overflow pipe, *g*, should be opened to indicate when it is full. If this phlegm be not sufficient to fill the lower boiler, the remaining quantity of liquid is allowed to flow in from the refrigerating basin, C, attached to the upper boiler, by opening the stopcock, *d*. As soon as the liquid flows out through the pipe, *g*, the stopcock of this, as well as the cock of the pipe, *d*, is closed, and the fire stirred. Shortly afterwards, when the steam from the lower boiler rises through the apparatus, the stopcock of the pipe, *n′*, is opened, that the hot water contained in the refrigerator, *m*, may descend to that attached to the boiler, L. After the whole of the water is run down, the tap, *n′*, is shut, and *i* and *k″* opened, to replenish both the refrigerating basins with cold water from the large condensing vessel, R. The second firing is about this time in progress, the liquid in the boiler is deprived of its alcohol in the manner as before explained, and the distillation of the charge is completed in about two hours. A similar mode of operation to that described takes place at each charge, irrespective of the alcoholic liquor submitted to distillation.

It will not be out of place here to offer a few words explanatory of the mode of torrefying the malt in the space between the cylinder, U, and the outer envelope, or casing, X.

The sprouted grain is introduced through the circular opening in the top, between the envelope, X, and the cylinder, U. The heat from the cylinder, U, is by this means rendered available for torrefying the grain; and this is a matter of great economy in a distillery, as by it the erection of a kiln, and the consumption of fuel required to heat it, are dispensed with. When the grain has dried to the proper degree, it is removed through the openings, *z′ z′*, and replaced by more moist malted grain, to undergo the same process.

Mr. MILLER, of Glasgow, secured a patent for a new still for the distillation of spiritous liquors, and the fermented wash of malt and grain. The novelty of this still lies in the employment of evaporating cones, having open spiral channels winding round their exterior. In other respects the still embodies the main features of all the principal distilling arrangements of the time, already described; namely, that of returning the products of the first condensation, which contain an excess of water, to the body of the apparatus for a further rectification.

Fig. 71 shows the principal parts of the still and worm; Fig. 72, a sectional view of the cone, which embodies the improvements. A is the body of the still or boiler, which is of ordinary construction. The head of the still, A′ A′ A′, consists of three cones, placed concentrically, B, C, D, but a small distance apart. Both surfaces of the cones, B and D, are plain, but round the exterior of the cone, C, an open spiral channel, X, winds from the top to the base. The position which this part occupies may be better understood from the detached view of the cones in Fig. 72, where X X shows the channel, and C the cone. A pipe, E, leads from the annular space between C and D to the wash-heater, F, which consists of a vessel filled with a number of small parallel pipes, and communicating with a low-wine condenser, G, which is placed in the upper part of the worm tub. The wash is supplied to the vessel, F, by a wash-charger reaching from the backs, and communicating with the vessel, F, at M; this, however, is not shown in the figure. I is a pipe which leads from the top of the outer cone, B, to the spirit condenser, K, which consists of a cylindrical case, inclined towards the still, and containing a number of pipes laid longitudinally, through which the gaseous products pass; it is filled with water supplied by a pipe not seen in the figure; the heated water is discharged through the pipe, Q. The pipe, K′, issues from the end of the spirit condenser, and enters the refrigerator, where it is united to the worm, L, placed in the bottom of the tub, W. O and *i* connect the condensing pipes in the vessels, K, F, and low-wine condensing worm, G, with the outer part of the cone, C; and the pipe, H, serves as a communication between the top of the wash-heater, F, and the body of the still, for the purpose of charging the latter.

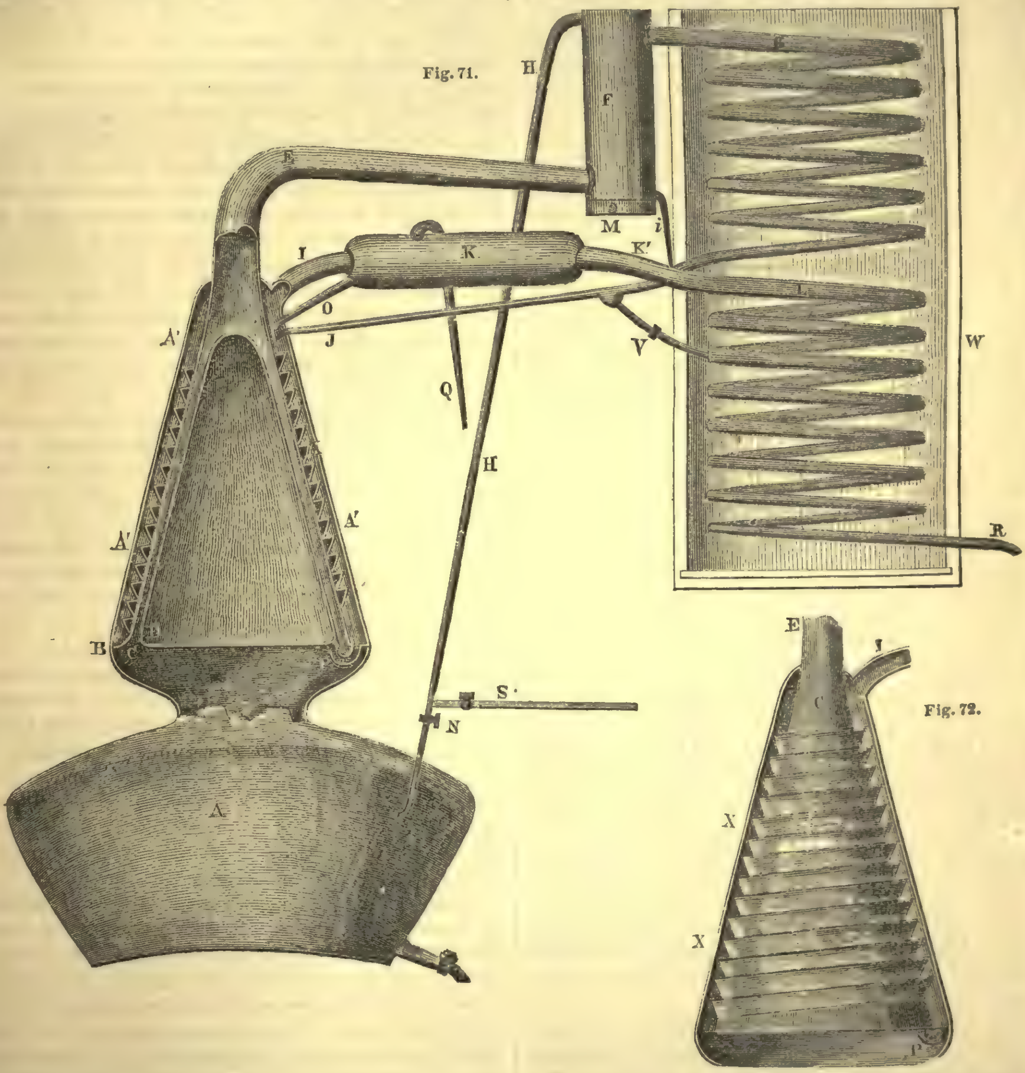


Fig. 71.

Fig. 72.

The following is the mode of working:—A quantity of wash is run into the still, A—which is supposed to be placed over an ordinary furnace—from the wash-heater, F, through the pipe, H, to the height of say three or four inches. As the wash boils, the vapor arising from it ascends the space in the still head, A′A′A′, between the cones, C and D, and through the pipe, E, into the wash-heater, F; part of the vapor is here condensed, and the remainder passes off into the low-wine condenser, G. The latent heat of the vapor is evolved in its passage through the vessel, F, and serves to raise the temperature of the liquid contained in it, after a while, to the boiling point; the condensed liquor in F, as also that which is formed in G, returns through the pipes, *i*, J, into the top of the space, B and C, in the still head, and flows into the channel, X, where it is reheated in its descent through this compartment to the base of the cone, by the simultaneous ascending vapor between C and D, and the portion thus evaporated flows off through the pipe, I, to the spirit condenser, K. That portion of the liquid which is not converted into vapor, is ejected from the cone, and received into the boiler through a pipe, P, to undergo another distillation.

In the spirit condenser, K, a further rectification takes place; all the finer parts of the spirit passing off through the pipe, K′, into the worm, L, where they are condensed and discharged through R into the spirit-back, while the coarser products that are condensed return through the pipe, O, into the canal, X, for a further purification. Whatever be the quantity of wash which is introduced at first into the still, no more should be allowed to enter till the whole of its alcohol is expelled. For this end the supply pipe, H, is furnished with a stopcock, N, and a branching pipe, S, for the purpose of drawing off any excess of wash into a tank appropriated to that purpose. Towards the end of the distillation, the weak faints may be run off from J, by means of a branch pipe, V, that enters the large condensing worm.

The Bushmills.—Before concluding the article on malt whisky, a short account of the Bushmills may prove interesting, as this spirit is said by many to claim pre-eminence over all others, in the same manner that genuine hollands is considered superior to any gins made in this country.

Bushmills is a small but very thriving market town in Ireland, situated upon the river Busk, or Bush, and about a mile and a half from the Giant's Causeway.

The town has long been celebrated for its superior malt whisky, there being two distilleries, one of which has been established about thirty, the other twenty, years.

In the oldest of these distilleries the spirit is made exclusively from malt, which is prepared in the ordinary way, excepting that peat is used in drying it. The quantity of malt wetted for each brewing is eighty bushels, from which only one mash is prepared for fermentation, the after-washings being retained, as usual, for exhausting fresh quantities of malt. In preparing the first mash, about eighteen to twenty gallons of water are used to each bushel of malt. Only as much water or small worts is let on as will wet throughout the whole of the malt; the temperature is 146° Fahr., and in fifteen minutes afterwards, the remaining quantity is run on at a heat of 155° to 160°.

After drawing off the first mash, nine hundred gallons of water are let down into the grist at a temperature of 170° to 175°, and after mashing from three-quarters to one hour and a quarter, the wort is let into the under-back, and pumped into the coppers. Nine hundred gallons more are used in the third mash, the temperature being 180° Fahr.; both these liquors are used in making the first mash on the next day's brewing, and on account of the density of the small worts, the malt used is from sixty-five to seventy bushels.

The density of the first mash, when let into the fermenting tun, is fifty pounds to the barrel as usual. None but the best of barm is employed in the fermentation; the quantity is one per cent. of the wort, one-half of which is added at the commencement, and the other when attenuation has reached 30 or 35. Attenuation is completed usually in forty-eight hours, though in variable weather a longer time is required; the quality of the malt also affects the quickness of the decomposition, but the chief cause of a good or bad fermentation is the yeast; the fermented worts are reduced in gravity to that of water, and frequently below this. The mash stills at the Bushmills factory are of the old description, and the manager states they are the best for making fine spirit, an assertion with which many will coincide.

The average yield in this establishment is from fourteen to sixteen gallons per quarter of eight bushels, but there is always a variation above or under these figures, according to the quality of the grist. The best spirit is made always in dry weather.

Potteen Whisky.—This far-famed spirit was some time ago more extensively manufactured throughout the kingdom than at present. It seems to be more than ever prized on account of its scarcity, and it bears a high price, particularly the Scotch and Irish. The singular flavor of the Irish produce is supposed to be caused by using turf for the exsiccation of the malt. DONOVAN relates that a few years back, being on a journey amongst the mountains in the most Northern parts of Ireland, he learned there was a potteen distillery at work; he despatched an emissary well known to the distiller, to procure him admission, which was granted. It was a place renowned for producing good whisky. The distillery was a small thatched cabin; there was a large turf fire kindled at one end, and confined by a semicircle of large stones, upon which a forty gallon tin vessel, serving the twofold purpose of a water-heater and a still body, was resting. An orifice in the roof, immediately over the fire, served as a chimney for the escape of the smoke after it had traversed the apartment. The fumes of the burning turf were so acrimonious as to produce a smarting of the eyes, which annoyance was got rid of by sitting down, owing to the fumes occupying the upper stratum only of the air; they consisted principally of pyroligneous acid.

The mash tun was a cask hooped with wood, at the under part of which, next the chimb, was an opening plugged with tow. This vessel had no false bottom; in place of it young heath was strewn, and over this a stratum of oat-husks. Here the mash of hot water and ground malt was occasionally mixed up for two hours; after which time the vent at the bottom was opened, and the worts were allowed to filter through the layers of oat-husks and heath. Mashing with hot water on the same grains was then repeated, and the worts were again withdrawn. The two worts being mixed in another cask, some yeast was added, and the fermentation allowed to proceed until it fell spontaneously, which happened in about three days. It was now ready for distillation, and was transferred into the tin boiler, which was capable of distilling a charge of forty gallons. A piece of soap, weighing about two ounces, was then thrown in to prevent its running foul; and the head, apparently a large tin pot with a tube in its side, was inverted upon the rim of the body, and luted with a paste made of oatmeal and water. The lateral tube was then luted into the worm, which was of copper of an inch and a half bore, coiled in a barrel for a flake-stand. The tail of the worm, where it emerged from the barrel, was calked with tow. The wash speedily came to a boil, and then water was thrown on the fire; for at this period is the chief danger of boiling over. The spirit almost immediately distilled; it was perfectly clear; and by its bead, this first running was inferred to be proof. Its flavor was really excellent; and it might well have passed for a spirit three months old. As soon as the upper stratum of water in the flake-stand became warm, a large pailful of cold water from an adjoining stream was dashed in with sufficient force to make the hot water run over, it being lighter; and this cooling process was continually resorted to. In this way, the singlings were drawn off in about two hours, and those from four distillations made one charge of the still to produce the potteen.

The malt was prepared by enclosing the barley in a sack, and soaking it for some time in bog water, which is deemed the best; then withdrawing and draining it for some time, after which it is made to germinate in the ordinary way. When it had grown sufficiently, it was conveyed in a sack to the kiln, along with some sacks of raw corn, for the purpose of concealment. The raw corn was spread out on the kiln, but during the night, when the kiln-owner had retired, the raw corn was removed, the malt spread, desiccated, and replaced by the raw grain before day. The owner of the corn drying on a kiln, sits up all night to watch it. In this way discovery was eluded, and the malting terminated. Besides the much-valued flavor of potteen, it had derived a part of its character owing to its being distilled entirely from malt. Now, however, about one-fourth of raw corn is generally added. From a bushel of this mixed grist, the potteen-maker obtains a gallon of spirit, of what is called three-to-one; or three glasses of spirit mixed with one glass of water afford proof spirit. This is, according to calculation, much below the produce that ought to be obtained.

The body of the still cost one pound, its head four shillings, the worm cost twenty-five shillings, the mash tun and flake-stand, twelve shillings; three pounds was, therefore, the value of the whole distillery. It is purposely conducted in this economical plan, as it holds out no inducement to informers or Excisemen. Sometimes they have been constructed on an extensive scale. It is very doubtful whether the aroma depends on the turf smoke, for it is stated that the spirit has the same taste and odor when coal is burned under the kiln. It is possible that the turf smoke may be absorbed by the spirit, for it is well known that there is a period of the alcoholic fermentation at which odors are apt to be retained. The peculiar flavor must certainly arise either from the turf or the bog water in which the malt is steeped. When dried in the kiln after steeping, the heat is often sufficient to char the bog extract remaining in the malt; consequently, this would communicate an agreeable smoky aroma to the spirit.

MOREWOOD gives the annexed interesting details on the subject of illicit distillation:—The spirit distilled from pure malt is considered superior to that made from a mixture of malt and raw grain. To assign a reason for this, would require an analysis and report of particulars of the process of malting; but it may be sufficient to observe, that the effects of the malting process are similar to those the grain undergoes in the course of vegetation, when sown in the earth. Illicit distillers, as if aware of the value of this metamorphosis, almost invariably use malted grain. From a want of scientific knowledge and proper utensils, they conduct their business in a different manner from that pursued by licensed traders. In preparing the malt, the sacks of barley are generally steeped in bog-holes or other places, where they remain forty-eight hours, or until completely saturated with the water. They are then drawn out and drained for ten or twelve hours. After this the grain is spread out upon the floor in a thick layer, and remains so till it begins to chip or germinate; it is turned occasionally, until all appears alike sprouted. It is afterwards spread by degrees, till such time as the buds show three points, and when these points have grown half way down the grains, by means of a regular heat, the particles are semi-transparent. At this stage it is spread thicker on the floor, and brought to a heat easily perceptible to the hand, then thrown into a round heap, and suffered to remain in that state for twenty-four hours, or longer; the latter is termed the rot or withering heap. It is then carried to the kiln and dried by turf; the kiln-head on which it is dried is covered with decayed straw, over which, if convenient, is placed haircloth or matting. The period of drying a kiln-head or crop, as it is termed, is commonly twenty-four hours, when directed by a person of experience. The grain, while on the kiln, is carefully turned by the hand, to expose every particle to the same heat, and to prepare it for coarse grinding. It is next taken to the still-house, which is usually a hovel or excavation near a running stream, or where there is a full supply of water. The quantity of malt to be brewed is commonly from sixteen to seventeen stones; after being bruised or mashed in the ordinary way, it is covered in the kiln with a lid or sacks, and suffered to repose for three or four hours. The worts are then drawn off, and cooled to a temperature regulated by the finger, no instrument being used for that purpose, and commonly to the same degree as that which is observed in regular distilleries; they are next put into a pipe or puncheon, with about a gallon of yeast; in an hour or two after the barm is added, fermentation begins, and in twenty-four hours afterwards, the attenuation is considered complete. Sometimes two brewings, after undergoing the fermenting process for about eighteen hours, are considered fit for the still; and in the ordinary course of working, a brewing is made every morning. The quantity of pure spirit drawn from these two brewings, is usually two hundred and twenty-three gallons, of one-to-two, or two-to-five; or, in other words, the spirit is of such a strength that it will bear one gallon of water to about two gallons of spirit, or two gallons of water to five of spirit, to bring it to proof. The usual strength at which illicit spirit is made, is from four to six over proof on Sykes' hydrometer; but sometimes it is as much as eight per cent., and in many cases it has been sold at a strength of thirty over proof.

In making the malt, and in the mode of distilling, the flavor is altogether formed; no machinery is employed in the still to keep the liquid from empyreuma.

In distilling the wash, the strong low-wines are separated from the weak, the latter being thrown back into the still with the succeeding charge of wash; a similar practice is observed in making spirit, the faints being put into the still with the next charge of low-wines. Thus the spirit is preserved pure and clear, nothing whatever being used in the distillation but a small quantity of soap thrown into the still with the pot-ale or refuse, to neutralize or keep down the yeast, as they term it, which would otherwise cause the run of the low-wines to become colored like the wash, or to get foul. It is a mistaken notion to suppose that soap is used only by the larger distillers, since it is considered an indispensable article by every person who understands the mode of working a still on the old system.

The spirit of these illicit stills has been long a favorite beverage in Ireland, being from malt without adulteration, and possessing a flavor which habit has rendered most agreeable. This, combined with the high duties on legally-distilled spirit, and the want of a ready market for the disposal of the grain of remote and mountainous districts, induced the people to embark in this contraband traffic to an extent which was not only injurious to the agriculture and revenue of the country, but to the morals and peaceful habits of the community. To such an extent was it carried, that in 1806, out of eleven million four hundred thousand and thirty gallons, the computed consumption of spirit in Ireland in that year, three million eight hundred thousand gallons were allowed to be the produce of illicit manufacturers, and in 1811, 1812, and 1813, there were no less than nineteen thousand and sixty-seven illicit distilleries destroyed by the revenue and military.

To put down this unlawful trade, various enactments were passed by the legislature, among which that of fining the townlands on which any portion of a still, wash, low-wines, or other materials for distillation were found, was not the least oppressive. The annual average of fines levied for seven years under the act for the suppression of this evil, amounted to fifty thousand nine hundred and eighty-nine pounds for all Ireland, while in one county alone, the sum paid in 1806, was two thousand six hundred and twenty pounds; in 1807, two thousand seven hundred and fifty; and in 1814, eighteen thousand one hundred and twenty-five. How could it be expected to be otherwise, when it was proved before the parliamentary commissioners, that many men were found to declare they had never done a day's work in their lives except at illicit distillation, and that they knew nothing else by which they could gain a livelihood?

Many interesting and curious facts might be related of the extraordinary contrivances of the people to evade the law and prevent detection, such as the artful construction of distilleries on the boundaries of townlands, in the caverns of mountains, on islands in lakes, on boats in rivers; of carrying away and secreting revenue officers for weeks together to prevent their giving testimony, the romantic manner of their treatment while in confinement, and the various other schemes and devices to defeat the intentions of the government.

Among these, **MOREWOOD** narrates the instance of a person who had constructed a distillery so artfully, that it eluded the vigilance of the most expert officers of Excise, though they knew of its existence in the neighborhood. A determined functionary of this staff resolved to find it out at all hazards, and on one moonlight night, alone, he followed a horse led by a peasant, having a sack across the back of the animal, which, he suspected, contained materials for this mysterious manufactory. When the horse had arrived at a certain place, the sack was removed from his back, and suddenly disappeared. The officer made his observations, returned to his residence, and having procured military assistance, repaired to the place where the horse had been unloaded. All was silent, the moon shone bright, the ground was unmarked by any peculiar appearance, and he was almost inclined, as well as those who accompanied him, to think that he had labored under a delusion. Perceiving, however, some brambles loosely scattered about the place, he proceeded to examine more minutely, and, on their removal, discovered some loose sods, under which was found a trap-door leading to a small cavern, at the bottom of which was a complete distillery at full work, supplied by a subterraneous stream, and the smoke conveyed from it through the windings of a tube that was made to communicate with the funnel of the chimney of the distiller's dwelling-house, situated at a considerable distance.

Another distillery has been known to be worked on the site of, and in conjunction with, a lime-kiln, which, from the kiln being continually in operation, kept the other for years without detection. So cunningly were some of those still-houses situated, and so artfully constructed, that the smoke proceeding from them was made to issue as if from burning heath or sods of peat ignited for manure. Their position was, for the most part, either on a commanding eminence, in the centre of a bog, or in a well-secured stronghold, but always calculated to prevent the identity of townland or proprietorship; while the portability and easy removal of the apparatus rendered the discovery and seizure of those stills difficult and hazardous. On the approach of a stranger, an alarm was given, either by deputing a messenger or sounding a horn, while the machinery was removed and the pot-ale always destroyed, or conveyed into receptacles under ground, prepared for such exigencies. Thus the still-hunter was often disappointed of his expected prize, the poor distiller put to the loss of many a brewing, and the Excise officer rendered the object of the hatred and vindictive feeling of the unreflecting peasantry.

The fines on townlands having been abolished, it was found necessary to adopt some other measure to put down illicit distillation. Recourse was therefore had to a revenue police, the Excise officers having too much other business to attend to, and the difficulty and expense of procuring regular military assistance being almost insurmountable. Accordingly, a revenue police was established in 1822, and was gradually augmented, in proportion to the exigency of the service. In 1826 this force amounted to thirty-two parties; in January, 1833, to fifty-seven parties; and in 1838, to seventy parties, amounting, including officers and men, to upwards of twelve hundred persons. They were distributed through those parts of the country in which prohibited distillation most prevailed; and though their exertions have been very great, yet they have but partially suppressed the evil. Their services will be best appreciated by an enumeration of the detections made by them in four successive years.—

	Stills.	Malt. Bushels.	Distilleries.	Worts. Gallons.	Spirits seized. Gallons.
1830, ...	804 ..	25,136 ..	1,788 ..	122,263 ..	624
1831, ...	123 ..	24,901 ..	1,479 ..	106,908 ..	353
1832, ...	974 ..	47,683 ..	2,299 ..	203,472 ..	1150
1833, ...	1537 ..	71,782 ..	3,300 ..	320,813 ..	6944

Of the many plans which have been laid to obstruct the revenue officers in the discharge of their duty, the following is not the least deserving of notice:—On the approach of the assizes of 1803, when many were about to be prosecuted for illicitly distilling, an officer, stationed at Dunfanaghy, in the county of Donegal, who was to support the informations, was suddenly seized, blindfolded, and carried away by a body of men in disguise, and brought to the island of Arran, on the Western coast. Thence he was conveyed to the islands of Goal, Innismay, *et cetera*, where he was closely confined, often threatened with the loss of life, and was even obliged, by way of humiliation for his active services, to assist in the working of an illicit still; while, like another Tantalus, the cup of pleasure was held to his parched lips, without the liberty of gratifying his thirsty desires. At the end of thirteen days, when the necessity for his confinement had ceased, he was again blindfolded, taken from the island, and sent a considerable distance into the interior of the country, where the mask was removed from his face, and he was allowed, in the solitude of night, to make his way to his disconsolate family, who, all the time, had looked upon his restoration as hopeless.

Another officer, on a similar occasion, was hurried from his bed, put into a sack, thrown across the back of a horse, and in this manner was conducted to the margin of a lake, where, in his own hearing, a consultation was held as to whether he should be drowned, by tying a stone to the sack and committing it to the deep, or be put to a more lingering and torturing death. In this awful state of suspense he was removed to a mountainous part of the country, where he was subjected to every kind of insult and privation, continually menaced with death in every shape of barbarity, led out at night as if about to be executed, and reconducted to his solitary habitation, anticipating a renewal of further cruelties. In this state he was retained for a considerable time, till the judge who presided at the assizes, during the trial of some persons for illicitly distilling, suspecting the parties as being accessary to this outrage, told them, that if the officer who had been taken away was not immediately liberated, he would pass such a sentence on them as would for ever put it out of their power to commit such another offence, and gave them but twenty-four hours for his restoration. This had the desired effect: the unfortunate man was again put into a sack, and restored to his family in the same manner as that in which he had been carried away.—*Morewood.*

Whisky is generally made in the United States from Indian corn; and in Cincinnati, where this grain abounds, there is so large a quantity of alcohol and whisky manufactured as to supply the Western and Southern markets.

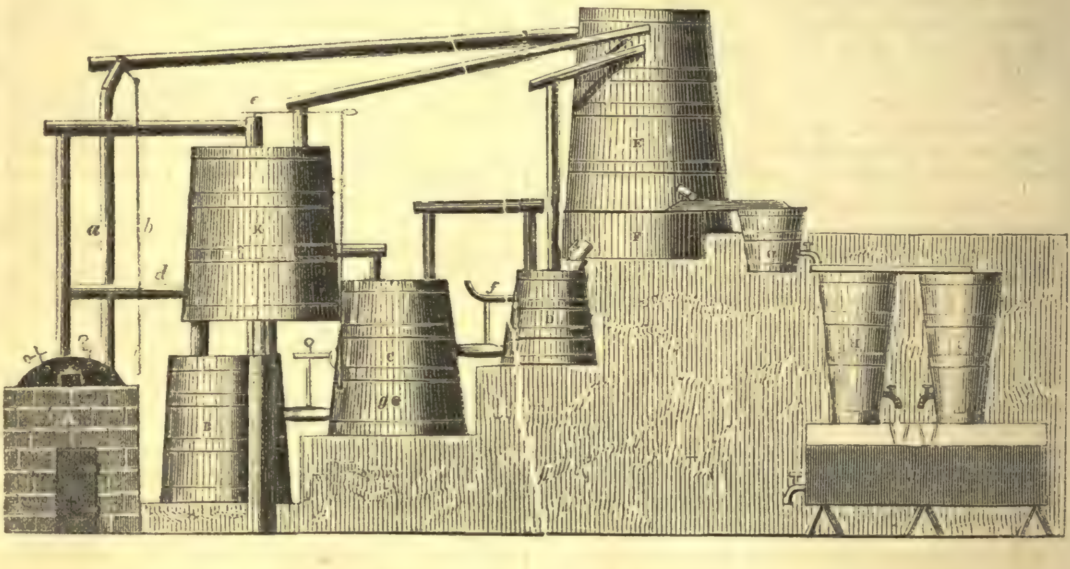
The opposition given of late by the temperance societies to intoxication, has diminished the consumption of spiritous liquors very much in the United States. Some States are prohibited by law from either manufacturing or vending ardent spirit of any kind, and they are using their utmost endeavors to have the same law passed by the legislatures of other States.

Numbers of distilleries are now at work in Canada; like those of their neighbors, they are mostly of wood, and worked by steam. In Pittsburg, and other parts of the United States, the whisky is purified by filtering it through charcoal coarsely ground. Seven miles from the city of Toronto is a large distillery, the annexed drawing and description of which—Fig. 73—are taken from MOREWOOD.

A is the brickwork, in which the iron boiler, with a cylindrical flue running through the centre, is partly enclosed. B and C are the first and second wooden stills, of the same size, being four feet eight inches at bottom, and four feet six inches at top, with an altitude of six feet; D is the doubling or low-wines' still, two feet ten inches at bottom, and two feet four inches at top, the height being three feet nine inches: E is the worm-tub, six feet at bottom, five feet at top, and nine feet high, supplied by a copious stream of water; F the low-wines' and faints' receiver: G is the recipient for the spirit previous to passing through the rectifiers or filtering vessels, H, I, and is two feet at bottom, two feet four inches at top, by two feet in height. The top diameter of H and I is three feet, and the bottom two feet, the altitude being five feet; they are filled with charcoal and other material, through which the liquor gradually descends in a limpid, gently-flowing current into J, the final receiver, or store cask. K is a tank or large vessel for holding warm water for distilling purposes, supplied from the top of the worm tub, the heat of which is supported by steam from the tube, *c*, connected with the boiler, and having a stopcock for regulation at *e*. The tank is a reservoir for supplying the mash tubs with water, of which, in the establishment, there are fourteen, each measuring three feet four inches by three feet six inches in diameter, ranged on a loft above the stills, in such a manner that, after the worts have undergone fermentation in these tubs, they are let down by a leader or trough into the second still, C, at *g*. When the first charge is worked off, the remainder is let into the first still, and the second still is charged from the mash-keeve. To facilitate the operation, there are pipes with proper stopcocks from still to still, such as that at *f*; and it will be perceived that the whole process of distillation is effected by means of steam admitted through the tube, *d*, projecting from the main upright pipe of the boiler into the first still, B, and so proceeding by other pipes through the other stills. The tubes which convey the steam into the stills descend to nearly three or four inches from the bottom.

All the vessels and pipes, as well as the stills, are made of pine; the pipes are nine inches square, with a bore of two and a half inches in diameter. The steam-boiler is seven feet deep, the height of which, at the fire place, is eight feet, and it is supplied by water from the worm-tub by the pipe, *a*, regulated by a stopcock or ball of lead which is worked by the cord, *b*. It is not necessary to describe the other vessels of this arrangement, as they are similar to those employed in the distilleries of Scotland and Ireland. The greatest disadvantage attending it, is the liability of the timber becoming soon unserviceable when the operations are discontinued for any time; but in a country like Canada, where wood is so plentiful, this inconvenience is readily repaired.

Fig. 73.



The wash is usually made from rye, wheat, or Indian corn, with a mixture of one-twentieth part of barley malt, or one pound to the bushel of mixed grain; many use a larger quantity. This is ground or crushed in a mill, and then mashed with water, at a heat ranging between 158° and 162°; others work at a temperature so high as 180° and 190° Fahr., but this is uncommon. When mashed, a cover is immediately put on the tubs, or keeves, in order to preserve the heat as much as possible. The mash is then permitted to remain, with an occasional agitation by the rakes for about two hours, until the menstruum acquires its proper sweetness; at this stage, cold water is added to reduce the heat to 60° or 64°, but mostly to 70° or 74°, when yeast is added. This yeast is home made, in country places in particular, but in the towns it is usually procured from brewers. The tubs or keeves are again covered and allowed to repose until completely fermented, when the distilling commences. The grains and all are put into the still. Brewing and distilling are generally carried on in the Canadas from October till May.

No duty is charged on malt in the Canadas, and the distillers have, therefore, every encouragement to make use of it in what proportion they may deem necessary for the production of a good and palatable spirit; the ale made from it is celebrated in the West Indies.

RECTIFICATION OF SPIRIT.—On recapitulating the steps through which the production of spirit has been traced, it will be seen that at first the grain—sometimes mixed with malt—is crushed in order to allow hot water to act more readily upon its mealy ingredients; next, the mashing takes place and worts result; then the fermentation of the worts commences, whereby the saccharine principle is resolved into alcohol; finally, this alcohol is, by successive distillations, separated from its greater portion of water, and *plain British spirit* is obtained. Alcohol, so highly prized by chemists, the various forms of spiritous liquors known as hollands, whisky, gin, British brandy, and rum, and the cordials under the name of peppermint, cloves, aniseed, *et cetera*, are produced by the rectifier, from plain spirit purchased from the distiller; consequently, the two branches are perfectly distinct. British spirit is but little known in the form in which it leaves the distillery, because it receives from the rectifier the exclusive property by which it is rendered a household word. One of the most extensive and elegant rectifying distilleries is that of Messrs. CHILD and SON, in London, and from all accounts the resources of modern science are there brought to bear on this particular branch of manufacture with tact and discrimination.

The manufacturer of whisky, or any of the other alcoholic liquors, rarely purifies the products, but disposes of them to the rectifying distiller, whose business it is to remove from them any contaminations which render them disagreeable or highly injurious. If, however, the fabricator conducts this operation as well as the original preparation from the grain, a distinct part of his premises is allotted to the work, according to legal enactments, and a peculiar process followed, which will be here considered.

All spiritous liquors are identical, when the extraneous bodies from which such liquors are obtained have been removed, with this exception, that a variable amount of water is present in them; they are more or less concentrated solutions of *alcohol*, whose properties have been fully given; thus, the alcohol from wine, rum, malt, potatoes, carrots, beets, grasses, and various other sources, is the same in quality, provided all the other solid and liquid impurities be removed. A single distillation of the spiritous portions of those liquids will not effect their purification, and where volatile oils are present, distillation merely, how often soever repeated, will not separate them, for these volatile impurities pass over during distillation; hence, the spirit procured from wines by simple distillation will have their peculiar flavor; beer, when distilled, will, for the same reason, yield alcohol possessing the abominable taste of the yeast; malt spirit will have the disagreeable qualities of faints from the presence of an oil of an acrid bad taste; and potato spirit the physical characteristics of fusel oil, or oil of potatoes. Thus, the disagreeableness or fragrancy of distilled products is, as in the case of malt and potato spirit, due to the presence of an essential oil, derived from the source of the alcoholic liquid. The chief object of the distiller in rectifying spirit is the removal of these oily bodies in order to procure a pure alcohol, from which, by the aid of other ingredients, he can fabricate liquors imitating those more costly products which are formed naturally, such as the better varieties of brandy, gin, whisky, and all the other kinds of liquors and cordials which are in daily request as favorite beverages with the community.

Caustic potassa—under the name of grey salts—or soda, is added to unite with the oil; pearl-ash—white salts—is employed with the view of combining with the water, as was mentioned under the formation of absolute alcohol in the commencement of this article, as well as to take up the fatty or oily impurities. The alkali combines with the oil, giving a soap which remains in the still, while the spirit passes off divested of its impurities. It has been ascertained, that when carbonated alkali is used, the distillate contains some of the salt, as it affects litmus and turmeric papers—hence this method cannot always be followed. Every rectifying distiller in the kingdom fabricates cognacs, genevas, usquebaughs, *et cetera*, from the disagreeable low-wines of the malt distiller, or from the foul potato or carrot spirit of foreign manufacturers.

All of these spirits, as they come from the first distillation of the respective mashes, are called low wines or *singlings*, and are charged with oils, and unfit for any use while in that state. When they are redistilled, the first portion which comes over is much purer, and contains less water than the singlings; this is called the *foreshot.* So much of this spirit as can be produced without the smell of faints, is retained as whisky, and the remaining portion is diluted and submitted to further distillation.

The strength of whisky, as sent out from the manufactory, is generally about twenty-five per cent. over hydrometer proof, on Dicas' scale. On a further distillation of this whisky, a spirit is obtained which marks about forty-six per cent. over proof, and is about the strength of spirit of wine in general; of this, about eighty gallons are obtained from one hundred gallons of ordinary whisky, of twenty-five per cent. over proof. A further distillation affords a liquid of spec. grav. 0·820, which is the strongest spirit that can be obtained by mere distillation.

When various compounds, such as chloride of calcium, caustic lime, sulphate of soda, or acetate of potassa, have been employed, either for the purpose of uniting with water or oily matter in the liquors, portions of these bodies are, according to the statements of DUBUE, invariably found in the distillate. The same authority states, that when spirit was distilled over calcined alum, the condensed liquid reddened litmus paper, but when sulphuric acid was added in small quantity to the spirit, not exceeding thirty-eight degrees of the areometer, the product which came over was found to be quite pure. Alumina, or aluminous clay, well washed and dried, was found capable of abstracting small quantities of water from spirit, and no portion of it passed over into the receiver.

Charcoal is a means by which the disagreeable flavor of spiritous liquors is removed. It has been made the subject of investigation by several chemists, among whom, LÖWITZ ascertained that, by distilling common malt spirit over charcoal, its peculiar bad smell was removed; this is also effected by merely agitating the two together. He performed ten experiments, with one pound of common spirit for each operation, and a variable quantity of charcoal, from half a drachm to five ounces, with the following results:—

Half a drachm of charcoal scarcely altered the smell, and the liquor did not clear for six months.

One drachm of the charcoal had no better effect in removing the bad flavor and odor; but cleared it in four months.

Two drachms cleared the spirit in one month.

Four drachms removed the smell in a very sensible degree, and the spirit became clear in one month.

One ounce of the charcoal completely freed the spirit from the bad smell, and clarified it in a fortnight.

An ounce and a half cleared it in eight days; three ounces in five days; four ounces in twenty-four hours; and five ounces in two hours.

From the experiments of HAHNEMAN and KELS, it would appear that the use of charcoal in purifying spirit confers a peculiar fiery taste, whether the alcoholic liquor be drawn off by distillation, or by agitating the mixture, then allowing the charcoal to subside, and afterwards decanting the clear liquid; its use is therefore objectionable.

KUNKEL was the first chemist who made the essential oils, contained in spirit, the object of research. His method of rectification was to dilute largely with water and distil, by which the product was much improved in flavor.

Wood-ashes had, for a long time, been almost in general use in the rectification of spiritous liquors; their beneficial effects are due to the amount of alkali they contain, which enters into combination with the small quantity of acid formed in the spirit, as well as with the oily matters. It would appear that filtration through hydrate of lime has the effect of removing some of the essential oils from spirit; the practice had been followed in France, particularly among those who carried on an illicit trade by adding an odoriferous oil to their brandies, and then entering them at the Customs as perfumes.

The fragrant principle was removed, subsequently, by diluting with water, and filtering through lime, slaked in the air, which had the effect of separating the oil, provided it had not been present in great excess.

ZEIZE affirms that agitation with a small quantity of hypochlorite of lime has the effect of destroying the essential oil, and that the spirit, after distillation from the lime compound, resembles brandy in flavor; most likely a small quantity of chloroform imparts the bouquet. Milk, according to the views of M. CADET DE VAUX, has the peculiar property of removing the bad flavor from the spirit obtained from the wines of various mellow and sweet fruits. This is effected by one or two distillations with milk, and the spirits obtained are almost identical, and much improved, notwithstanding that they were procured from quite different sources.

The rectifying distiller now only considers the removal of the oil, since the improved apparatus affords an alcohol of any strength which is required in all ordinary cases. The proportion of salts employed for removing the oil from the crude proof spirit of the large wash distillers, is about

4 lbs. grey salts, and
4 lbs. white salts,

to every seven hundred gallons of the ordinary product. Where the distiller infers that an unusual quantity of the foul oil is present, the proportion of salt is increased, and sulphuric acid is also added in order to ameliorate the flavor of the spirit by giving rise to an ether. The salts are dissolved in about two gallons of liquid, and if the commercial article be used, it is found necessary to remove the sedimentary impurities by filtration. This alkaline solution is mixed with the liquid, and the distillation commenced. If the ordinary common still be employed, great attention must be paid to the fire; for if it be not timely slackened when the liquid first boils, there is much risk of the still *running foul*, that is, boiling over through the neck of the still, which occurrence would of course spoil the operation; when, on the contrary, the improved stills, such as COFFEY'S and others, which have been already described, are used, no danger is to be apprehended from this evil. In rectifying faints, 80 under proof, the following method is used:—The spirit is mixed with the proper quantity of alkali, and the stills charged with this; the first portions that come over after the still is brought down, are collected separately, till the spirit runs at about proof, when it is turned off into another receiver; the result of this rectification—the common still being employed—will be about ten per cent. over proof. On rectifying a second time, the distillate at first marks forty-three per cent., and is collected till it indicates thirty; it is then conducted into another back until reduced to ten per cent. over proof, and the residual portion, after this strength, is received in the faints-back. A third rectification will afford a spirit of fifty-three per cent. over proof, or spirit of wine. In the second rectification, only one half the quantity of salts employed in the first operation is made use of; and in the third, it is customary to add about four pounds of animal charcoal, and ten pounds of coarse grained common salt, to every hundred gallons, to cleanse the still. At the distillery of Messrs. JAMES MULLENEUX and SONS, in Liverpool, where M. ST. MARC'S stills are erected, they can rectify twelve hundred gallons of proof ordinary wash spirit in ten hours, and obtain a product, if required, of sixty per cent. over proof, and stronger; but in that case a longer time is required to distil the whole contents, but the trouble of repeated distillations—as when the ordinary still is worked—is dispensed with, besides a considerable saving in labor and fuel is effected.

GENEVA.—This far-famed liquor has been long the subject of study among distillers. Many trials have been made to produce a spirit equal in quality to that imported, but with very indifferent success.

The subjoined particulars were communicated to the late Dr. THOMSON, by a gentleman who sojourned in Holland for several years, solely for the purpose of learning the process followed in the manufacture of the Dutch hollands or *geneva*. One hundred and twelve pounds of barley malt, and two hundred and twenty-eight pounds of ryemeal, are mashed with four hundred and sixty gallons of water, at 162° Fahr.; after infusion has taken place, cold water is added to bring the strength to forty-five pounds per barrel, or spec. grav. 1·047, at which strength, after it has cooled to 80° Fahr., it is run into the fermenting tun. To the contents of the fermenting back, which is about five hundred gallons, half a gallon of good yeast is added, fermentation speedily sets in, the temperature rises to about 90°, and the attenuation is complete in forty-eight hours. After attenuation of the wash, from twelve to fifteen pounds per barrel of saccharine matter remain undecomposed in the fermented liquor. The wash and grains are then introduced into the still, and the whole of the low-wines distilled over; these are subjected to a second distillation, and the distillate after rectification is the famous *geneva*. A few juniper-berries and sometimes hops are added in the rectification, to impart to the spirit a peculiar terebinthine flavor.

Some peculiarities are seen in this concise account of the process followed in Holland, namely, the imperfect attenuation of the wort, and the small amount of yeast employed in bringing it about. Double the quantity of spirits are obtained from the worts of the distillers in this kingdom, as is produced from those of Holland, according to the example just given. It is very probable that the large amount of yeast used by British and Irish distillers, and the last efforts tried to effect an attenuation as low as possible, are the very means which communicate a flavor to the spirit so different from the Dutch. The only liquor in this country which can bear any comparison with that of Holland, is perhaps the illicit product. A manufactory for the production of hollands was instituted some few years since at Maidstone, in Kent. It never became popular, and after languishing a few years, ended in bankruptcy. It has never since been revived. Indeed, according to the present state of the Excise regulations, it would be preposterous to attempt it, and this is only one of the numerous instances of the many obstacles in the way of private industry and enterprise, inflicted by the laws of this country.

British Gin is, for the most part, manufactured by the rectifiers of the low-wines of the Scotch and English spirit or whisky fabricators. The mode of procedure is to rectify the spirit from the faints by one or more distillations, and then to flavor it with berries and various other bodies. These processes are carried on generally in a most absurd and uncouth fashion, as appears by the following few receipts from the note-book of one of the most extensive and respectable distillery rectifiers in the kingdom.

The still is charged with three hundred gallons of liquor, and six hundred and fifty gallons of spirit from a previous rectification, to which are added—

95 lbs. German juniper berries,
95 lbs. coriander seeds,
47 lbs. crushed almond cake,
2 lbs. angelica root, and
6 lbs. liquorice powder.

The whole is well rummaged, distillation commenced, and after the worm is cleansed by the first portions drawn over into the faints-back, about one hundred and sixty gallons are run into forcing-back No. 4, then turned off into back No. 3, till it runs one-to-nine, or eleven per cent. over proof, when it is turned into faints-back No. 8.

About four hundred gallons are found in back No. 3. Liquor is run into back No. 4, to reduce it to fifty per cent. under proof; it is fined by throwing into it two pounds of alum dissolved in boiling water, and leaving it to rest for about eight hours, after which this *low gin* is pumped into back No. 3, containing the remainder of the charge to bring it to twenty-two per cent. under proof; then the whole is pumped into store casks for use; the result being one thousand one hundred gallons.

Another standard receipt for *Cordial Gin*: Take seven hundred gallons of the product of the second rectification—if the improved stills are used, the product of the first distillation answers—and mix with it the following ingredients:—

70 lbs. German juniper berries,
56 lbs. coriander seeds,
5 lbs. almond cake, crushed or broken,
1½ lb. orris root, broken,
2½ lbs. angelica root, cut,
½ lb. cardamom, or, instead of this,
6 lbs. liquorice powder are sometimes added.

Force the first running of the working, or about two hundred gallons, by reducing it to fifty under proof, adding three quarters of a pound of alum, boiled in two quarts of water. In adopting this receipt, make a double working of it, with twice the quantity of the ingredients. Work in the flavoring in the first charge of rectified spirits, having in the back two or three inches of the usual charge, to make up with liquor, and prevent the bottom of the still from injury by the charring of the large amount of ingredients depositing upon it. Turn the distillate into another back, and reduce to fifty per cent. *under proof;* force with a pound and a half of alum, and pump into fining cask; then charge with rectified spirits, and work into back containing goods from preceding charge. Run down gin from store cask, and make up to strength required—seventeen to twenty-two under proof.

Another receipt for the manufacture of Cordial Gin, the charge being nine hundred and fifty gallons, is the following:—

100 lbs. juniper berries,
70 lbs. coriander seeds,
2 lbs. orris root,
1 lb. angelica root,
2 lbs. calamus root,
½ lb. cardamom seeds.

The operations being the same as noted in the preceding.

For a *Fine Gin*,—the distillation of which is carried on, for the most part, in the same manner as the above,—take

960 gallons of spirit, hydrometer proof,
96 lbs. German juniper berries,
6 lbs. coriander seeds,
4 lbs. grains of paradise,
4 lbs. angelica root,
2 lbs. orris root,
2 lbs. calamus root,
2 lbs. orange peel,
80 or 90 lbs. of liquorice powder are occasionally added, to impart color and sweetness.

Plain or *London Gin* is made in the following proportions:—

700 gallons of the second rectification,
70 lbs. German juniper berries,
70 lbs. coriander seeds,
3½ lbs. almond cake,
1½ lb. angelica root,
6 lbs. liquorice powder.

For the manufacture of *West Country Gin*, the annexed is the process:—Introduce into the still seven hundred gallons of the second rectification, and flavor with

14 lbs. German berries,
1½ lb. calamus root, cut, and
8 lbs. sulphuric acid.

This gin is much used in Cornwall, and particularly in the Western counties of England; it is also used in making British hollands, and in that case is mixed with about five per cent of fine gin, reduced to twenty-two under proof with liquor.

For *Geneva.*—Charge of still being nine hundred and fifty gallons of second rectification, the proportions are:—

84 lbs. juniper berries,
112 lbs. coriander seeds,
6 lbs. cassia buds,
4 lbs. angelica root,
6 lbs. calamus root,
6 lbs. almond cake,
½ lb. cardamom.

Plain Geneva.—For nine hundred and fifty gallons of spirit of second rectification, take

84 lbs. juniper berries,
84 lbs. coriander seeds,
2 lbs. almond cake,
2 lbs. orris root,
2 lbs. calamus.

Another prescription for making Geneva—and one which is much esteemed—is the following:—Add to nine hundred and fifty gallons—

14 lbs. grey salts, and
4 lbs. white salts.

The rectification to be conducted with the usual care. At the second operation, add—

168 lbs. juniper berries,
74 lbs. coriander seeds,
12 lbs. almond cake,
8 lbs. grains of paradise,
8 lbs. angelica root,
1 lb. cardamom,
2 lbs. calamus.

It is of importance, and deserves attention, to consider, that in making gin with a high degree of flavor, the distillate, or flavored liquor drawn over, is very apt to turn blue on being diluted, to prevent which is very often a difficult task. In preparing such liquors, however, it would be the most advantageous and satisfactory way to have two stills, and to divide the charge between them. To one-half the amount, the whole of the spices and flavoring matters are added, and the liquid drawn off into two backs till it runs at eleven over proof. One of the backs is reduced as low as one in two, or fifty per cent. under proof, which ought always to be observed, as in making gin it should on no account exceed this strength, but may be two or three per cent. under, without being disadvantageous. About two to four pounds of alum are dissolved in hot water, and this solution is thrown into the back with the flavored spirit or goods, the whole briskly stirred, then pumped into a store vat, and left to fine over night; in the morning it will be clear, and is run into the back containing the second portion of the rectified spirit, without flavoring, and diluted to twenty-two or seventeen per cent. under proof.

In making gin of a less flavor, or where two stills cannot be employed, it is necessary to have a forcing-back to fine. To this forcing-back a small cask is attached, to enable the operator to pump off the low gin to the portion of strong in the back. The process followed in order to prevent the *bluing*, is to flavor and charge the still, and to run off into the forcing-back, till it is ascertained at the worm end that the spirit will not change color on being diluted with water, and when this happens, it is turned off into the working-back to the usual strength. The gin is then reduced in the forcing-back to fifty per cent. under proof, and the aluminous solution poured in, on the following day, when the liquor has clarified, it is pumped to the making vat to the remainder of the charge, and brought down to the strength required. If too weak, it may be raised by adding the best spirit of wine in the required quantity.

In France, an exceedingly fine gin is produced by fermenting a portion of juniper berries bruised with four parts of barley meal, or ground malt, proceeding throughout the succeeding part of the operation in the same way as when making grain spirit.

Another method practised is the following:—Boil during half an hour two gallons of bruised juniper berries in four gallons of water; put this into a barrel capable of containing six gallons; add to it at first four pounds of rye bread that has been dried and reduced to powder, then some aromatic, according to the fancy of the manufacturer, and two pounds of brown sugar. At the end of a month the liquor is converted into an agreeable wine, which, when distilled, affords a spirit much esteemed, and commanding a high price.

Having given the several incongruous mixtures used by the rectifiers in preparing their gins, the Editor now introduces a particular notice of each substance mentioned, with a description of the oil derived from it, and its properties, to enable the manufacturer to become better acquainted with the nature of the roots, seeds, and essences, that give to his liquors their peculiar fragrancy, astringency, *et cetera;* moreover, the information thus laid before him, may induce him to make use of those only that are serviceable in imparting the desired aroma. If spirits are at all wholesome (?), they must be more so in a pure than in a degraded state; consequently, it should be the aim of the fabricator to elevate rather than to deprave the taste of the consumer.

Cardamom.—The oil obtained from this seed is colorless, of an agreeable odor, and strong aromatic burning taste; the seeds are used in Abyssinia as a condiment, and in medicine; they are stimulant, tonic, stomachic, and carminative, and yield nearly five per cent. of essential oil, the composition of which is $C_{10} H_8$.

Grains of Paradise.—The volatile oil has a light yellow color, a camphoraceous smell, and a hot, penetrating taste; the seeds are esteemed in Africa as the most wholesome of spices, and are generally used by the natives to season their food; they are also used for medicinal and other purposes, as stomachic and cordial stimulants. Gins possessing a very peppery flavor, acquire it from grains of paradise, which yield half a per cent. of oil.

Almond Cake.—This is the residual cake of bitter almonds, after expressing the fixed oil. When distilled, it affords a volatile oil, which has a golden yellow color, an agreeable odor, and an acrid bitter taste. Substances or liquids flavored with bitter almonds may act injuriously, owing to the presence of hydrocyanic acid.

Angelica Root.—This root grows most abundantly in Northern Europe; its taste is at first sweet, then hot, aromatic, and bitter.

Calamus Root.—The taste of this root is due to the oil, which is sharp and sweetish; the yield of oil is about one-hundredth per cent. It is obtained by distilling with water, and is used for flavoring aromatic vinegar.

Orange Peel.—The peel of the orange yields the oil proper, which has the strong odor of the rind.

Lemon Peel.—The oil is obtained both by expression and by distillation. It is chiefly imported from Portugal, Italy, and the South of France. Pure lemon oil is very fluid, of an agreeable odor, and colorless. Its taste is pleasant but pungent, and it is, therefore, often used in culinary purposes as a substitute for the peel; the flavor, however, which it imparts, frequently savors of turpentine, and is never so agreeable as that communicated by the fresh rind of the fruit. Oil of lemon and oil of turpentine are isomeric.

Juniper Berries.—What the distiller prizes in this berry is its volatile essence, which is an oily liquid, isomeric with the preceding, and with oil of turpentine; their smell is also very similar, hence the origin of the supposition that London gin is sometimes mixed with the latter. Oil of juniper is the most powerful of all diuretics, and gives to the urine the smell of violets. It promotes perspiration and relieves flatulency; consequently, gin is recommended in many diseases of the urinary organs.

Coriander.—The seeds have a strong smell, and medicinally are considered as stomachic and carminative; they are used in sweetmeats, in certain stomachic liqueurs, and, in some countries, in cooking. They contain about half a per cent. of volatile oil, to which they owe their fragrancy, and on this account the seeds are used in rectifying operations.

Orris Root is the root of *Iris Florentina*, a white flowering species of iris found in the South of Europe. It has an agreeable odor resembling violets, and is sometimes used in perfumed powders. In its dried state it is employed as a pectoral and expectorant, and is sometimes made into little balls for issues, called orris peas.

Liquorice.—A plant of the genus Glycyrrhiza. The root abounds with a sweet juice, much used in demulcent compositions.

Cassia.—This plant furnishes buds which consist of the calyx surrounding and nearly encircling the young ovary. They bear some resemblance to a clove, but are smaller, and when fresh have a rich cinnamon flavor. They are used for the same purposes as cinnamon and cloves. The bark and oil are powerful stimulants. Oils of cassia and cinnamon, when quite fresh, have the formula $C_{20} H_{11} O_2$. On exposure to the air they rapidly absorb oxygen, yielding a considerable quantity of cinnamic acid.

It occurs to the Editor that most of the roots or seeds have, so far as their oils or essences are concerned, very analogous properties; and since their virtue in distillation with the spirit is to communicate their oily or fragrant principle, why not add a few drops of each of the oils at once to the pure spirit, to procure the desired liquor, and by this means obviate the necessity of distilling, and the risk of injury to the stills by the mixtures mentioned, which appear to have no atomic rule for their basis?

BRANDY.—This alcoholic liquor forms an extensive trade in the South of Europe, and it is generally obtained from the high-colored, white, or pale-red wines of those countries, but is often manufactured from inferior articles, such as the refuse wine and the marcs of the wine press.

Distillation of the wines is the only thing necessary to procure this spirit; hence, the richer the wine in alcohol, the greater will be the yield of brandy. A simple test with an alcoholometer will determine for the distiller the value of the wine as to the yield of brandy; but many other circumstances, independent of the manufacture, enhance the quality of the product.

Thus, the white wines do not always afford more alcohol than the red, but the spirit is of a much finer quality from the former. The reason of this is, that they contain more of the essential oil of the grapes. It is also a singular fact, that those wines which carry with them a certain taste of the soil, communicate it to the brandy derived from them by distillation; thus, the wines of Selluel, in Dauphiné, give a certain brandy which has the flavor and the taste of Florentine iris; those of St. Pierre, in Vivarais, give a spirit which smells of the violet, and so of many other varieties.

Wines of the countries nearest the Mediterranean furnish the largest proportion of brandy, which diminishes as the grapes grow in more Northern countries. The wines of the South of France yield one-fourth of brandy, some even one-third, while in the North of France, only about one-eighth, or even one-tenth of brandy is afforded.

The fabricator of the better qualities of brandy invariably distils the white wines; first, as was before stated, because often a greater yield of brandy is obtained, and this of a better quality than from the red wines; and, secondly, because those wines fine sooner, so that they may be distilled into brandy before the red wines are ready for this operation.

The stills employed on the Continent are those of DEROSNE and LAUGIER, in France; of PISTORIUS, in Germany; ST. MARC'S is also used in the distillation of wine. With these stills, the spirit comes over of any requisite strength, up to the strongest spirit of wine; but when the ordinary still is employed, the receiver is changed when the vapor arising from the boiler only feebly ignites, and the *eau-de-vie-seconde*, or *repasse*, is collected by itself, till the whole of the alcohol in the wine has been exhausted. The liquid remaining in the still is called *vinasse.*

The *campaign*, or distilling season, in France, is from the beginning of October to the end of May.

The following is an average of the yield of brandy which some of the wines afford by distillation:—

1000 Litres	of wine of St. Gilles, in the environs of Montpellier, afford of 3/6 brandy,.....	150 litres.
" "	of good wine of calcareous soils, ...	140 "
" "	of wines of fertile soils near Montpellier,	100 "
" "	of wines of soils producing much grapes,	100 "

The brandy, as sold in France, is generally of two degrees of gravity; these strengths are thus designated —*à preuve de Holland*, and *à preuve d'huile;* the former varies from 18° to 20° of Beaumé. The stronger liquids are valued according to the quantity of *eau de vie*, or brandy *à preuve de Holland*, that a given quantity will furnish on the addition of the proper proportion of water. These strengths are usually twelve, namely, *five-six*, *four-five*, *three-four*, *two-three*, *three-five*, *four-seven*, *five-nine*, *six-eleven*, *three-six*, *three-seven*, *three-eight*, and *three-nine*, but the last is rarely made. The meaning of these strengths is understood in the following sense:—if a spirit be five-six, five parts of the spirit will give a liquor *à preuve de Holland*, when added to six measures of water; if three-six, three measures when added to six of water will yield a spirit of the same standard, and so of the remainder.

The spirit five-six strength is of a specific gravity 0·9237, or 22° Beaumé; but all the other strengths are subject to variation on account of the uncertainty of the strength *à preuve de Holland*, as before shown. Wines, when distilled carefully from a clean apparatus, yield a distillate which is colorless or nearly so, and when it is wished to retain it in this state, vessels of glass or stoneware are employed. After being put in casks and left in them, the clear liquor acquires a little color by extracting the soluble matters of the wood; the flavor, however, is not materially affected if the casks be not newly made; when new casks are used, the tannic acid of the wood, which is generally oak, communicates a deep color and astringency of taste which is quite foreign to the brandy.

The brandy from different localities, and even from a different variety of grape grown on the same place, possesses, as already remarked, an aroma characteristic of the wine whence it is obtained, and which is readily perceptible to those well versed in the trade. An experienced taster will readily distinguish the brandies of Languedoc, Bordeaux, Armagnac, Cognac, Aunis, Rochelle, Orleans, Barcelona, Naples, *et cetera;* further, he can say from what species of fruit it is derived; and he will also discern minute shades of difference in the qualities of various brandies from the same source. Real cognac is obtained from the distillation of the choicest wines, every regard being paid to the proper degree of cleanliness which should be observed in the various utensils through which it has to pass. In the improved forms of still a very superior article is obtained from inferior wines, but the proportion of essential oils in such wines divests the brandy of that aromatic flavor which is an inherent property in the better sort of wine, and which is observable in a very distinct degree in the brandies procured from them.

An inferior variety of brandy, or *eau de vie de Marcs*, is obtained by distilling the dark-red wines of Portugal, Spain, and other wine-growing countries, the lies deposited by wines on keeping, the marcs or refuse of the grapes from the vine-press, the scrapings of wine casks, *et cetera.*

Distillation is carried on in the ordinary way, but as the flavor is not so much regarded, the spirit is drawn off rapidly, and at a high temperature. The marcs from the vine-press are prepared for the purpose of distillation by breaking the cakes up into pieces, and throwing them into water. A temperature of 70° to 80° Fahr. is kept up, and in the course of a short time fermentation sets in; when this has ceased, the solution is racked off and distilled. The first distillate has a whitish color, and is called *blanquette*, but this on redistillation yields a spirit of 22° or 24° Beaumé. One pound of brandy is produced from eighty-five to ninety pounds of cake.

The fermentation of the cakes is sometimes effected in large pits, where they are covered with earth. The progress of fermentation is known by thrusting the hand into the heap. When the temperature decreases, the fermentation is said to be finished; the contents are then taken out, water in proper quantity added, and distilled. By this process a hundred pounds of marcs yield one pound of brandy. When such liquors are distilled, the sedimentary matter subsides, and is apt to carbonize on the bottom of the copper still, and thus communicates a smoky flavor to the distilled liquor, in addition to a hot fiery taste proceeding from the essential oil—fusel oil or amylic alcohol—of the skin of the fruit. AUBERGIER has proved that a few drops of this energetic compound are sufficient to taint a pipe of one hundred and thirty-three gallons of pure spirit. In some distilleries the apparatus is furnished with agitators to keep the contents in motion. Other manufacturers insert into the body of the still a basket to retain the sediment accompanying the fermented liquor, and thus contact with the lower part of the still is prevented. M. REBOUL'S process is to inject steam from a boiler into the still by means of a coil of piping. The stills in this case are large wooden boxes, to which worms are adapted in the usual way, and the whole of the alcohol is driven over by steam heat. M. CURANDAU'S apparatus consists of a still, the neck of which is as wide as the body, and three feet in height; brackets are placed at the distance of nine inches in the neck of the still, which support several partitions; these are provided with short pipes, pierced with holes, to allow the vapors to circulate freely from the body of the still. The neck being affixed, and the first partition introduced, wine lies are poured in, which are filtered by the perforated partition; then the second, and a further quantity of lies, and so on till all the partitions are inserted and the lies are about six inches thick on each.

If the liquid drained from the marcs or lies be not sufficient to fill the still, water is added to make up the proper quantity. Heat is then applied, and the steam, as it passes off, expels the last portions of spirit from the solid particles retained by the partitions in the neck of the still. Most of the inferior kinds of brandy contain an acid which partly unites with the oil from the grapes, rendering the taste of the spirit unpleasant; agitation with a little quicklime has been recommended, which not only removes the acid, but also the oil in a great degree. The matter left in the still when dried and burned, yields an alkaline carbonate, which is often preferred to potassa, or the commercial article, in dyeing operations.

Spirits of this class are used by the lower order of people in France, but on account of their hot fiery taste, they are often preferred in England and other Northern countries to a more genial produce. Cognac and Armagnac brandies contain about half their weight of water, and owe their fragrancy to the smaller amount and less disagreeable nature of their fusel oil, so that the aroma, indigenous to the wine, is readily perceptible in their odor and taste.

Enanthic ether is another constituent which imparts a nice aroma to wines, and passes into the brandy. **Pelouze** first proved this odorous principle of wine to be a compound ether. **Mulder** detected the same in the oil of grain-spirit, and in other fermented liquors, and it is from this that quinces derive their distinctive perfume. The specific gravity of this ether is 0·86217, and its composition the following:—

	Atomic weight.	Centesimally represented.		
		Theory.	Pelouze.	Muspratt.
18 Eqs. Carbon,	108	72	72·020	72·006
18 Eqs. Hydrogen,	18	12	12·050	12·103
3 Eqs. Oxygen,	24	16	15·930	15·891
1 Eq. Enanthic ether,	150	100	100·000	100·000

Or—

	Atomic weight.	Per cent.
1 Eq. Ether,	37	24·66
1 Eq. Acid,	113	75·34
	150	100·00

In cognac, *et cetera*, it is probable that the aromatic portion condenses sooner than a strong spiritous fluid, for the first sorts are only distilled to the spec. grav. 0·922; and by redistilling to obtain a stronger alcoholic liquid, much of the aroma remains in the residuary matter of the alembic.

The effect of heat on several of the substances contained in wines, merits the attention of the distiller. A little too high a temperature might destroy a whole distillate, as empyreumatic and other products would be generated. When, to save expense in carriage, the spirit is rectified to a much higher degree than the above, the dealer, on receiving it at Paris, reduces it to the market proof strength by the addition of water or of a little fragrant weak brandy; but in this manner the brandy produced is not equal to that derived from the distillation of Cognac wine, at an incipient heat. This may be readily proved by submitting to distillation, with every precaution, brandy of a superior quality; if the resulting spirit be then brought down to the ordinary strength with water, it will be plainly perceived that the liquid has been considerably deteriorated by the operation. Genuine French brandy evinces a red reaction with litmus paper, owing to a minute portion of acid; it also contains an ether, and, when kept for a considerable period in casks, it acquires an astringency which impairs its quality.

The brandy sold in England is, for the most part, artificial—the fabrication of the rectifying distiller. The following receipt is given by Dr. **Ure**:—Dilute the pure alcohol to the proof pitch, and add to every hundred pounds weight of it from half a pound to a pound of argol—crude winestone—dissolved in water, some bruised French plums, and a quart of good cognac. Distil this mixture over a gentle fire, in an alembic provided with an agitator. The addition of brandy and argol introduces enanthic ether, and if a little acetic ether be added to the distillate, the whole imparts the peculiar taste of genuine cognac brandy; color with burned sugar, if necessary, and add a little tannic acid to impart astringency.

An example is here given, on the small scale, for the artificial formation of this beverage; but the course followed by the rectifier is somewhat different, as will be seen from the subsequent few examples, which are transcribed from the private work-book of a very extensive rectifying distiller. The source is generally the common low wines of the grain distillers, which are rectified in the usual way, by distillation with caustic salts, as has been already described.

To every five hundred gallons of this spirit, about twenty-five gallons of the best French wine-vinegar are added, and the whole well rummaged in the mixing-back; the mixture is then pumped into the still, and a further quantity of a weaker spirit run into the back, in order to clear it of the last traces of vinegar—this liquor is also pumped into the still to make up. From fifty-six to sixty pounds of coarse-grained common salt are now mixed with the liquid in the still, together with from eight to ten pounds of concentrated sulphuric acid, keeping the whole in brisk motion during the addition of the latter, to protect the still from the action of the acid. The fire is then lighted, and the still brought down and worked till the spirit shows a strength of fourteen over proof, or one-to-seven. It is customary to turn off into the faints-back at a lower degree of strength, and collect the remaining quantity of faints; in such a case, however, the quality of the spirit is not so good. From every five hundred gallons of the charging, five hundred to five hundred and ten gallons of spirit, marking forty-two per cent. over proof, are obtained. This is mixed with from four hundred to four hundred and fifty gallons of liquor, and pumped into the British brandy store-vat. Twenty to twenty-five gallons of *fruit tincture*, fifteen gallons of brandy flavor, and eight to ten gallons of good coloring, are then introduced into the piece, the whole well rummaged, and left to fine. It is considered an improvement to fine with skimmed milk. Some distillers prefer to introduce distilled vinegar in the proportion of fifteen to twenty gallons to a thousand gallons of the compounded liquor in the store cask, instead of adding it previous to distillation, as before mentioned.

Another receipt, which is followed for the most part in the distillery from which these details were obtained, using a multiple of the numbers, is next given.

Three hundred gallons of proof spirit are distilled with the proper addition of caustic salts, taking all the precautions mentioned in the preceding, under Rectification of Spirits, and the distillate is received into the spirit-back till it runs at ten over proof. The remaining spirit is turned into the faints-back, and is then made up with four hundred and fifty gallons of spirit, twenty-two under proof, twenty gallons of *prune tincture*, twenty gallons of distilled vinegar, and eight gallons of good coloring matter.

When flavored faints are cleansed, charcoal is employed in the rectification with sulphuric acid.

Raspberry Brandy.—In manufacturing raspberry brandy, the subjoined is the process:—For one thousand gallons of the brandy, take

460 gallons of raspberry tincture,
115 gallons of cherry tincture,
240 gallons of sweets,
96 gallons of British brandy, 22 U.P.
89 gallons of liquor;

rummage the whole well, and force or fine with isinglass.

Cherry Brandy.—For the fabrication of one thousand gallons, take

575 gallons of cherry tincture,
253 gallons of sweets,
92 gallons of British brandy 22 U.P., and
80 gallons of liquor;

the whole to be well agitated in brandy-piece, and forced with isinglass.

Raspberry tincture is made as follows:—Take a brandy-piece with head out, and screen over the cock; put in fifty gallons of clean rectified spirit of twenty-two under proof, then fill the cask with raspberries. In three weeks or a month, draw off the whole of the tincture into a clean cask, and add to the fruit, a second time, twenty-five gallons of spirit of twenty-two under proof; let this remain upon the raspberries a month longer, and then draw this off, and add it to the first tincture; after which the whole of the tincture remaining in the fruit is to be pressed out and added to that already obtained. The cake is then broken up and steeped in a rum puncheon with the head out, forty gallons of spirits are added, the whole contents briskly agitated from time to time for three or four days, and pressed well after drawing off the solution. This liquor is employed in making up the raspberry brandy instead of water.

Cherry tincture is made in the same manner as the raspberry, by substituting the one fruit for the other.

For prune tincture cover fifty-six pounds of prunes, thoroughly broken up, with twenty gallons of clean spirit of wine, and after being allowed to stand for eight or ten days, rack off; the refuse fruit is washed twice with liquor, and the residue is then thrown away.

Many rectifiers prepare a brandy flavor as follows:—To one hundred gallons spirit—clean faints, fifty-four over proof—add

100 gallons of good strong vinegar,
4 gallons of spirit of nitre,

in a back, and mix the whole thoroughly; cover closely, and the next day run it into the still with

8 lbs. of nitric acid,
10 lbs. of almond cake,
5 lbs. of orris root, and
2 lbs. of lemon peel;

work the still slowly, and turn off at proof strength.

In making up brandy, ten per cent. of the above flavoring is employed, but more or less may be used to suit the taste of the consumer.

Brandy is distilled in Switzerland from the refuse of the grapes after the juice is pressed out, as follows:—Large casks are filled with the skins, which are squeezed as compactly as possible, and are covered closely to prevent the access of air; fermentation usually commences in about three days, and when it has finished, which requires a considerable time, it is deemed ready for the still. When the distillation is to take place, the fermented mass is mixed with a due proportion of water, to reduce it to a proper consistence for the action of the fire, which is moderately applied to prevent empyreuma. It is said that a vessel containing thirty-two cubic feet of this material will yield ten gallons of pure brandy.

RUM.—Molasses is the name given to the sirup which remains after the crystallization of sugar; it is, in fact, the mother liquor of sugar. This sirup, diluted with a sufficient quantity of water, undergoes the vinous fermentation, and by distillation yields a spirit, called in the colonies *rum*, or *taffia;* the name given to it, in the Isle of France and Madagascar, is *guildive.* This spirit is of excellent quality, very *recherché* when prepared with proper precaution, and particularly relished when it is very old. The best rum is that which is made solely from molasses; but that, in the fermentation of which is left the debris of the sugar-cane, froth, *et cetera*, always retains a sharp disagreeable acid, and frequently acquires an empyreuma, on which account it is given to the negroes who work in the sugar-houses, and is consequently called *negro rum.* In the fermented liquor from which the rum is distilled, acetic acid sometimes exists in large quantities, accompanying the ardent spirit, without forming ether; but it is the nature of this acid to produce, in the heat and vapor of distillation, a certain portion of strong spirit containing acetic ether, which, from its extreme volatility, rises in the first process of distillation, giving to the vapor a most disagreeable taste and smell; hence the colonial saying, that the rum becomes *too hot* if rectified like the European spirits. The cause of this is easily explained: the rectified spirit only forms a part of the charge of the still, and contains, nevertheless, *all* the acetic ether. The skilful fabricators, who pride themselves on making these strong spirits most agreeable to the taste, take great care in cleaning the keeves from all kinds of vegetal matter or refuse incapable of producing vinous fermentation, or such substances as have a tendency to putrefy, because the putrescent matter retards the action, and gives a savor which is communicated to the distilled spirit. The Chinese, who prepare the famous arrack of Batavia, which, without contradiction, is the best of all rums, take much care in rectifying it, mixing with it during distillation a composition called *ragie*, in which is cinnamon and anise-seed, in such proportion as not to be perceived either by smell or taste, being only sufficient to do away with the otherwise nauseous odor of the liquor. The Madagascars throw in leaves of trefoil. The Asiatics mix with it the bark of a kind of thorny acacia, called *pattay.* Some persons put into the still, with the grape, the leaves of a tree named *attier* in the East Indies, and *pommier cannelle* at St. Domingo—*œnona squammosa*—which have a light agreeable odor. Others have tried, with success, the mixture of peach leaves. All these substances impart to strong liquors a pleasant bouquet and taste, which prove that they are used to disguise the smell of the spirit, and to give it unctuousness.

The chief seats of the distillation of this spirit are the East and West Indies, America, and France. It is strange that the Chinese, who produce so much sugar annually, and who, consequently, might manufacture large quantities of rum from molasses, have not hitherto attempted to distil this article.

The Editor transcribes the following account of the fabrication of this spirit in the West Indies, from MOREWOOD:—

From the liquor of the cane, which runs warm from the coppers through a trough to a receiver prepared for that purpose, the skimmings are taken, and, with some of the liquor itself, are pumped from a cistern containing from three hundred to eight hundred gallons, when the fluid is mixed with water and molasses in the proportion of twenty-five gallons to one hundred. If this mixture be sufficiently blended together in the vats, which in some plantations amount to thirty, it is covered over with boards or mats of plantain leaves, and allowed to ferment for three or four days, or longer, should there be a want of yeast or other ferment to make it work, which often occurs at the commencement of the season. When reduced to a due degree of acidity, which is ascertained by the subsidence of the fermentation, it is run into a still proportioned to the vat, and wrought off as low-wines, in which state it is put into the still again. The first run, or discharge, after it is thus returned to the still, is taken off for *high*-wines, as they are termed, or strong rum, in the proportion of 25 to 300 gallons, the strength of which, when tried by a glass-bead instrument, is from 18° to 22°. The second run of the still, which is drawn off in cans, and carried by negroes to another vessel, is of a strength from 23° to 26°. From these two runnings of the still, the rum exported from the colony of Demerara is made up. Any deficiency in the strength of the second distillation is compensated by an addition from the first, which is always stronger than that exported, and of too ardent a nature to be used by itself, 25° being colony proof.

In the Windward Islands, one-third of the skimmings is mixed with one-third of the lies, and one-third of water. When these begin to ferment, which they usually do in twenty-four hours, the first mixture of molasses takes place in the proportion of six gallons for every hundred gallons of the fermenting liquor, and a day or two afterwards an additional quantity of molasses is added. The fermentation is tempered by the addition of cold or warm water. *Dunder*, a term unfamiliar to the ear of a European distiller, is the lies or feculencies of former distillations, serving all the purposes of yeast in the fermentation. It is derived from a Spanish word, *redunder*, the same as *redundans* in Latin, and is well known among the planters in the West Indies. The attenuating properties of this ferment are such, that the materials with which it is mixed are said to yield a much greater proportion of spirit than could be obtained if they were fermented without it: it serves the same purpose as jalap mixed with molasses, which has been sometimes employed in Great Britain for cutting down the frothy head at the close of fermentation; and it is usually preserved from one year to another for this purpose, in such large quantities as to fill most of the backs or fermenting tuns. Dunder soon becomes covered with so thick a film as to exclude the air, and the sediment leaves the intermediate fluid pure, of a bright amber color, which, when carefully drawn off, is employed as already described, in proportions suited to the nature of the fermentation; to this dunder may be attributed the best flavor of the rum. Besides this very essential ingredient, various mixtures are used in the fermenting process, such as tartar, nitre, sea-water, or common salt.

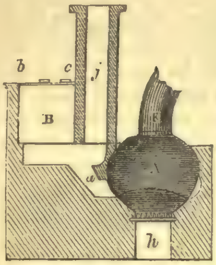
In well-conducted distilleries, much attention is paid to the management of the proper quantity of water employed in the preparation of the liquor. Before commencing, the various boilers and keeves are thoroughly washed and freed from saline matter, by hot or cold water.

In the beginning of the distilling season, more sugar is employed than is afterwards found requisite; the reason of this is, that the distiller has no good lies, and very little molasses to add to the mass; besides, the scum or froth from the sugar is not so rich from the first boiling of the season as in the months of March, April, and May, which is the most favorable time. The following proportions succeed well at starting:—For every one hundred and thirty-six gallons content of the vat, pour in sixty-one gallons of scum, seven of molasses, and sixty-eight of water. When the lies or dunder are good, equal quantities of skimmings, lies, and water are employed, and for every hundred gallons of this mixture, ten of molasses are added. Should the pressing-mill be not in operation, and skimmings cannot be obtained, it is found advantageous to employ equal parts of lies and water, and with every one hundred and thirty-six gallons of the compound, twenty-seven of molasses are mixed. With mixtures such as these, the distiller can obtain from ten to fifteen per cent. of rum, and other products; but this quantity depends very much upon the quality of the ingredients operated upon, as also upon the state of the weather and time of distillation; hence, an intelligent distiller varies the proportion of the bodies submitted to fermentation.

Rum differs from what is termed sugar spirit, for it contains more of the natural aroma, or essential oil of the sugar-cane. When the West India distillers have enough of matter, they mix the water with it, and allow it to ferment in the ordinary way; the fermentation proceeds slowly at first, on account of the scarcity of the yeast, but as soon as sufficient ferment has been produced, it operates quickly on the whole mass till the attenuation is finished. This liquid is then distilled, and produces a spirit of great strength, nearly equal to alcohol, which they name *double-distilled rum*, or *double rum*. The spirit is more easily concentrated if much liquid be submitted to distillation, but in the course of this operation it yields such a large amount of oily matter, that it cannot be used for a considerable time. For preserving the rum, either for exportation or other purposes, it is found useful to make the double rum so as to form alcohol, or ardent spirit. In this state it occupies only half the volume of the ordinary liquid, and can be diluted with water to suit the taste of the consumer, or to the common strength.

The still for the most part used in those islands, and by which a great saving of fuel is effected, is represented in the annexed engraving—Fig. 74. It consists of two distinct parts: A is the boiler, and B the vessel which contains the fermented wash, to be heated previous to its introduction into the still. The boiler and preparer are placed in such relative positions, that the heat of the fire, after doing the required service to A, passes under the vessel, B, and thus communicates heat to the liquid. The plan of the construction is seen in Fig. 75, where the arrows show the course of the flue under both these vessels. The waste heat enters the chimney by a damper-opening at the back. *a* is the passage from the fire under the preparer; *b*, a lid screwed firmly on the vessel, B, which resists the pressure of any vapor generated in this vessel; *c*, a safety valve; *j*, the chimney; *h*, the fire-door; K, the tube which carries off the vapors to the condenser attached to the alembic, which communicates by a pipe not shown, with the preparer, B.

Fig. 74.



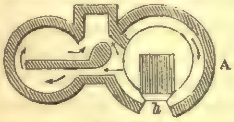
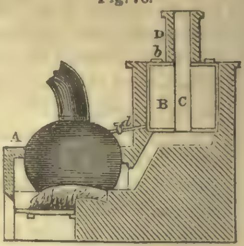


Fig. 75.

When operations commence, the preparer is filled with the fermented liquor, and likewise the still, to a proper height; the fire is then lighted, and the liquid in the alembic very soon boils, and that contained in the preparer at the same time acquires a temperature approaching ebullition, by the waste heat communicated from the flue beneath this vessel. As soon as the matter in the boiler becomes exhausted of its alcohol, the fire is slackened, the residuary liquid drawn off by the discharge-cock, and the boiler replenished by opening the stopcock of the pipe which connects the alembic and preparer. The fire is again urged, the vessel, B, refilled with fresh liquor, and the distillation proceeded with, as in the previous instance.

Another form of apparatus used by the West Indians is seen in the engravings, Figs. 76 and 77. This still, and preparer, differ only slightly from the preceding. A is the boiler, B the preparer; and the mode of communicating heat to the latter is seen in the plan—Fig. 77—where the course of the heat from the fire is indicated by the arrows, till it enters the circular space of brickwork called the *bonnet;* from this it traverses the perpendicular pipe, C, passing through the middle of the preparer, and thence into the chimney, D. *b* is the lid of the preparer, and *d* a pipe that connects this vessel with the boiler. This arrangement has an advantage over the common furnace, by the larger proportion of heat it communicates to the boiler on account of the winding course of the flue, and any extra caloric is made useful in heating the liquor in the vessel, B.

Fig. 76.



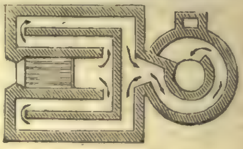
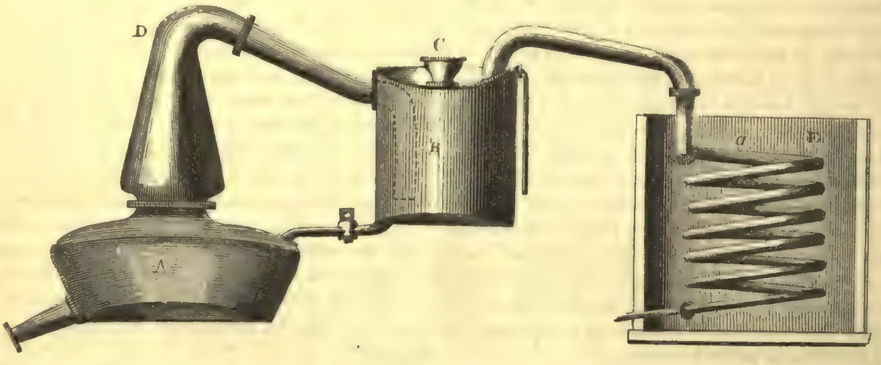


Fig. 77.

The annexed form of still—Fig. 78—is frequently exported to the West Indies. It consists of the boiler, A, with an elongated conical head, D; the preparer, B, into which the wash is introduced by the funnel-basin, C; and the condenser, E, where the spiritous vapor is liquefied in passing through the numerous convolutions of the worm, *a*. The peculiarity of this form of still consists in the communication of the pipe, D, with the preparer, B, by which means the vapor from A is partially condensed in the preparer. The vapor is carried to within a few inches of the bottom of the vessel, B, as shown in the figure by the dotted continuation of D; the liquor in B is heated by the aqueous vapor condensed in it, as well as by the spiritous vapor which passes through it uncondensed to the worm, *a*. By this arrangement fuel is economized, and a stronger spirit is procured at one distillation.

Fig. 78.



In some of the islands, a still makes about two hundred and twenty gallons of rum daily; these are produced from about five hundred and thirty gallons of low wines, or a hundred and thirteen of rum may be procured from twelve hundred gallons of wash. This liquor is so strong that olive oil will sink in it, and by one rectification it is made to approach the strength of alcohol. The process of distillation is in general slow, and much caution is observed in the condensation of the spirit. To provide against a scarcity of water, which often occurs in the islands, they preserve in large tanks a sufficiency of rain-water to enable them to mix the molasses, *et cetera*, and to cool the worm of the still. As the water becomes heated in the worm-tub, it is carried to coolers or cisterns, and when cold it serves again for refrigeration. In most of the islands, the curing-houses for sugar, and the distilleries for rum, are constructed on the sides of canals, and the canes carried to them from the plantation, either in boats or by negroes. Five or six immense copper boilers are kept in each of these houses, and the greatest cleanliness is observed in the distillery; a precaution of immense importance, which must contribute largely to the strength and purity of the rum. In Jamaica, the operations go on without intermission; the negroes being formed into divisions or relays, who relieve each other at regular intervals. The richness of flavor peculiar to this spirit, and which has rendered it famous in all parts of the world, is undoubtedly derived from the raw juice and the fragments of the sugar-cane, which are mashed and fermented with the other materials in the tun. The essential oil of the cane is thus imparted to the wash, and carried over in the distillation; for sugar, when fermented and distilled by itself, yields a spirit possessing no peculiar flavor different from other ordinary alcoholic liquors. Time adds much to the mildness and value of rum; but the planters, by the addition of pine-apple juice, impart to it the virtue which is conferred by age.

A superior quality of rum is manufactured in the colony of Demérara, where, according to the account of BOLINGBROKE, distillation has been carried to a high state of perfection by the perseverance and skill of several scientific men, who have caused the rum of this district, and that of Essequibo, to be as much prized in the American market as Jamaica rum is relished in England. In Brazil, large quantities of rum are manufactured, which are exported to America and to most European nations. The process followed is rude and simple. The wash is generally fermented in large earthen jars, but no fixed rules, to regulate the quantity of molasses which should be operated upon, are observed. A strong lie is said to be poured on the sirup, in order to thicken and purify it. The lie is obtained by burning a plant of the *polygonum* species, called by the Indians *cataýa*, and infusing the ashes in water. This plant has a bitter pungent taste, and is considered of use in making rum. The stills are mere earthen jars, with a long narrow neck, on the top of which is placed a head or cap, having at one side a pipe of about six inches long; to this adapter a copper tube, four feet in length, is connected, which passes through an earthen vessel sufficiently large to hold a quantity of water for the condensation of the spirit, and this contrivance is made to answer the purpose of both worm and worm-tub.

Until lately, it was a custom with the planters to dispose of their molasses to small distillers, who, possessing one or two of these stills, procured a living by making rum; but the introduction of copper stills from Europe has produced such a reformation in distillation, that at present the whole quantity of molasses resulting from the sugar-houses of the plantations is manufactured into rum by the proprietor.

To calculate the cost of rum to the sugar planter is difficult: in general, it is estimated that one-fourth of the entire produce of a plantation may, in point of value, consist of rum, and, accordingly, one-fourth of the expenditure may be taken as the first cost of the rum, and the remaining three-fourths as that of the sugar. Some say that the charge of making rum bears a similar proportion to that of home-made spirits, but this is an erroneous assumption. Rum is made from the molasses, or that part of the cane-juice which will not crystallize into sugar, as also from the scum which is taken off during the saccharific process, and which in sweetness is equal to one-fifth of molasses. Take, as a standard, a distillery on a plantation producing 250 hogsheads of sugar, yielding 15,000 gallons of molasses, and scum equal to 5,000 gallons, netting in all 20,000 gallons of molasses. These would produce about 15,000 gallons of proof rum, which, when brought to the British market, would be reduced by the voyage t about 13,500 gallons, the average loss being ten pe cent. These would cost the manufacturer throughout the islands from 1s. 1d. to 1s. 4d. per gallon, independent of all charges for puncheons, freight, commission, and other unavoidable expenses.

From this statement, it must appear that the distiller of rum has little or no profit, but being the grower of the material, and having his capital embarked in the trade, he is compelled to manufacture it from necessity, and the sooner he can turn the article to account the better he is enabled to bear loss and meet his engagements.

In France, a large quantity of spirit is annually manufactured from the molasses of the beet-root sugar factories, of which a great many exist in that country. The better sort of molasses remaining after the refining of the sugar of the colonies, is too valuable to be converted into rum, but sometimes the inferior article is disposed of in this way. On the arrival of the molasses at the distillery, they are emptied into large cisterns perfectly free from any dampness which would cause them to ferment, and here they remain till required for use. The fermentation of molasses presents some difficulties; they must be properly mixed with water, in such proportion that the resulting liquid will not exceed 8° of Beaumé's areometer, at a temperature of 20° C. = 68° Fahr., which should always be the heat of the mixture. When too little water is used, the fermentation sets in too rapidly, the temperature becomes higher, and the acetous fermentation speedily ensues; on the contrary, when too much water is employed, the fermentation is inactive; in consequence of the low temperature a longer time is required, and generally bad results follow. These inconveniences can be overcome by attention to the directions about to be given.

It sometimes happens that the fermentation of the saccharine solution suddenly ceases, and cannot be revived by an increase of temperature, or addition of a stronger solution of molasses. This phenomenon is owing to the presence of lime and potassa, which are contained in almost all the molasses of beet-root sugar, and, in consequence of the alkaline reaction imparted by these substances to the liquid, the conversion of the sugar into alcohol is interrupted. This antifermenting property of alkaline bodies is very easily removed; it suffices to add a certain quantity of sulphuric acid to neutralize them and form sulphates, in which state they are inert. A slight excess of acid might be employed, without prejudice to the proper degree of attenuation, or to the taste of the product; for the molasses always contain salts of organic acids, with potassa, *et cetera*, which are decomposed by the sulphuric acid, and the organic acids are liberated. The sulphuric acid is to be added when the water is mixed with the molasses, and may vary in amount from half a per cent. of the weight of the latter, as a minimum, to one and a half per cent. as the maximum quantity. The molasses being comminuted with the water and acid, so that the solution stands at 8° of the areometer, about two per cent. of their weight of fresh barm, pressed and previously diluted with water, is added; the liquid is then strongly agitated, and left to ferment. The fermentation is made in a number of tuns whose size corresponds with that of the distilling apparatus, and by this arrangement the distiller is enabled, when the fermentation in one tun is finished, to distil the contents directly.

The fermented wash should never remain longer than twenty-four hours until it is distilled. From this it is manifest, that the distiller should be furnished with as many fermenting vessels as will permit him to have the contents of one tun daily ready for distillation, and one ready for charging each day; the intermediate tuns being in a higher state of fermentation, as their turn brings them nearer the proper time of their being distilled. All the tuns should be well covered, to prevent the contact of the atmosphere, and the acid fermentation taking place.

If molasses be fermented and distilled merely for the alcohol which they yield, the preceding directions relative to the proper dilution and strength upon the areometer answer best; some distillers, however, in addition to the alcohol, extract the alkaline salts, chiefly potassa, and in this case the preceding strength of 8° on the areometer would offer an inconvenience, inasmuch as a large amount of fuel would be consumed in evaporating the residuary liquid after the alcohol was expelled. To prevent such expenses for combustibles, an investigation was instituted to find out a means for fermenting the saccharine wash at a greater density than 8°, and the endeavor turned out successful. The high density is 14° of the areometer, and, in order to ferment such a solution without its passing to the acid fermentation, the following mode is adopted:—When a sweet wash of 14° B. is set to ferment, the temperature of the liquid rises to 30° C. = 86° Fahr. in twenty-four hours, at which degree the alcohol is readily transformed into acetic acid. To oppose the formation of acetic acid, from the high temperature already mentioned, it is necessary, as soon as the liquid marks 27° C. or 76·6° Fahr., to divide it into two equal portions, and add to each half as much molasses of 14° strength as it already contains. Previous to mixing the second portion of molasses with the fermenting liquor, they should be well agitated with two per cent. of their weight of barm. Fermentation is now allowed to proceed without apprehension of the temperature rising so high as to favor the acetous fermentation in the liquor.

M. **Laugier's** apparatus, which will be subsequently described, is expressly adapted for the distillation of fermented saccharine liquors, but wine or malt wash may also be distilled in it. It works upon the same principle as **Derosnes'** still, under a simpler construction. In France, where considerable quantities of molasses are converted into rum, and this apparatus is in operation, the distillery is divided into the store-room, where the stock of molasses is retained until required for use; the fermentation-room, which occupies another compartment; the stills a third; and the store-room for the finished spirit a fourth.

Several fermenting tuns are furnished of a size to correspond with the quantity of wash which the still is capable of working daily, and these tuns are worked in rotation, so that one may be worked off and ready for distillation each day; by this means the fermented liquor is prevented from being exposed to the air, and the formation of acetic acid wholly prevented.

A side view of the apparatus, as it appears set in brickwork, is seen in Fig. 79; A and C are sectional views of the boilers heated by the fire, *c*, under A, round which the flue passes; thence in the direction of the arrows round the second boiler, C, in a similar way, and afterwards into the chimney; G is the rectifying cylindrical vessel, and E the refrigerator where the spirit is condensed. The boiler, A, is furnished with two pipes; one of these is for discharging the contents when all the alcohol is expelled, and is furnished with a stopcock, *f;* the other pipe, *i i*, carries off the generated vapors to the next boiler, C, where it terminates in a perforated rose, within a short distance of the bottom of the vessel.

A pipe issuing from the bottom of C, and furnished with a stopcock, *j*, enters the first boiler, and terminates like the pipe, *i*, in a perforated rose, as seen at *k*. From C, the pipes, *m*, *n* and *l*, rise; *m* and *n* are connected with the rectifying apparatus in the cylindrical vessel, G; the former carries off the vapors generated in C, and the latter returns the liquid condensed in this vessel into the boiler. The pipe, *l*, serves to charge the boiler, C, from the rectifying apparatus. Two pipes, *o o* and L, unite the rectifier and the condenser; the former conducts the uncondensed vapors from the rectifier to the worm in the refrigerator, and the latter serves to replenish the vessel, G, with liquor from the refrigerator. The pipe, L, descends to within a short distance of the bottom of G, so as to have the colder liquid issuing in contact with the pipes which contain the warmer vapors. Another pipe, *p*, emerging from the cover of the rectifying vessel, conducts any vapor generated by the condensation in part of the distilled products of the boilers, A and C, to the condenser. The refrigerator is filled through the funnel tube, *t*, from the tank, *v*, by means of the pipe and stopcock, *u*. The manner of working the still is simple:—Liquor is allowed to enter the funnel tube, *t*, until it begins to flow down the pipe, *l l*, into the boiler, C; and as soon as this is observed, the stopcock, *j*, is opened, and the liquor admitted into the first boiler, until it rises a few inches above the rose, *k*, as shown by the glass gage, *g g;* the stopcock, *j*, is shut, and the liquor allowed to flow into C, until it rises above the end of the pipe, *l l*, which emerges into the liquor; this is shown by another gage pipe, *g′ g′*, attached to C. The stopcock, *u*, is now closed, and the fire urged under the first boiler, the contents of which very soon boil, and are partly converted into vapor, which is emitted to the next boiler through the pipe, *i i*. By means of the caloric abstracted from the vapor in passing through the liquid, and the heat communicated to the boiler by the flue which circulates round C, the contents of this vessel are also made to boil, and, like those of A, are partly vaporized; the vapor is forced through the pipe, *m*, into the rectifying vessel, where, by means of a peculiar arrangement of pipes—to be explained further on—the greater part of the watery vapor which is forced along from A and C is condensed, and falls back into the boilers through the pipe, *n*, to undergo a second distillation. The first portions of the vapor that enter this vessel are entirely condensed, in consequence of the liquid contained in it being as yet cold; but when, after a short time, the latent heat of the condensing vapor raises the temperature of this liquid so high that it will not condense any longer the richer alcoholic vapor, the latter rises through the pipe, *o o*, and enters the worm in the vessel, E, where complete resolution takes place, and the spirit produced flows out by the pipe, *q*. As soon as the liquor in the first boiler becomes exhausted, the fire is slackened for a short time, the contents discharged through the pipe and stopcock, *f*, and a further quantity admitted by the pipe and stopcock, *j*, from the boiler, C, and this again replenished by opening the stopcock, *u*, of the tank, *v*. The fire is again urged briskly, and thus the distillation proceeds successively, so as not to lose alcohol.

Fig. 79.

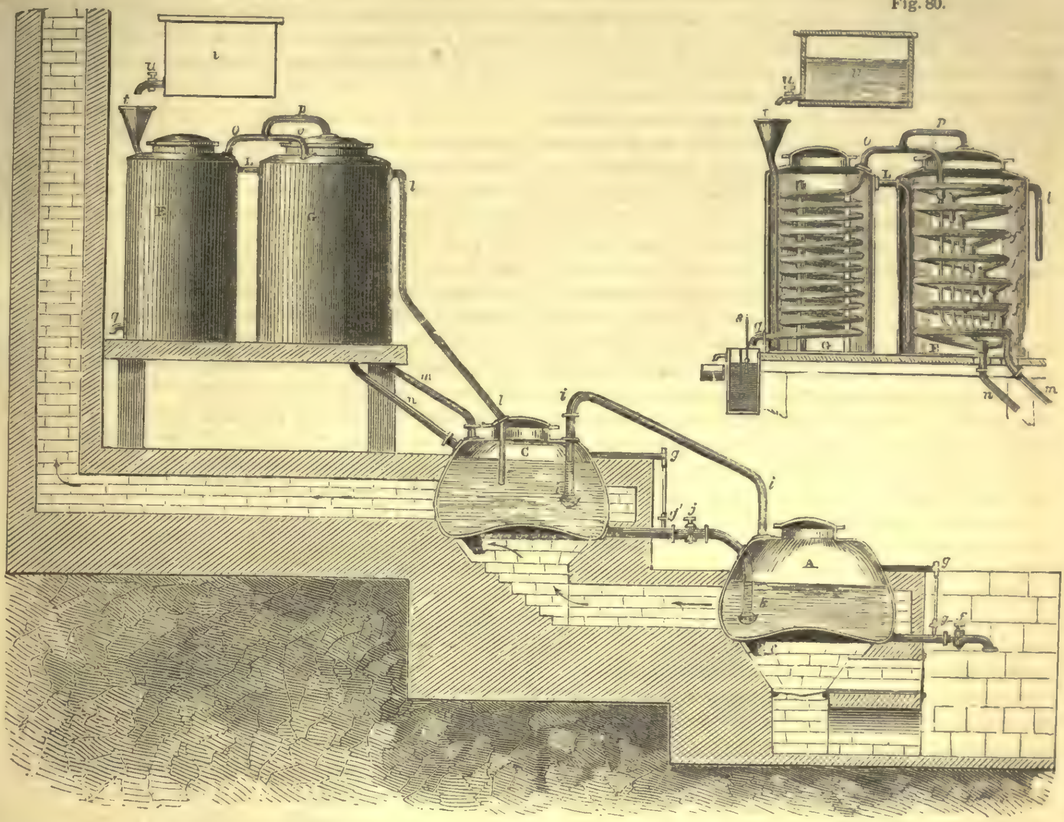


Fig. 80.

Fig. 80 is a section of the rectifier and refrigerator: in the first there are seven compartments formed of large circular pipes, as seen at $f\ f'\ f''\ f'''\ f^5\ f^6\ f^7$, each one of which terminates in a smaller pipe that meets the others in a ball at the end of the pipe, *n*. *o o* shows the connection of this apparatus with the refrigerating worm in the vessel, G; *p*, the pipe connected with *o o*, and emerging from the cover of the vessel, E, for the purpose of carrying off any vapors generating in the liquid surrounding the apparatus in this vessel. *t* is the funnel pipe, reaching to the bottom of the refrigerator; and *q* the termination of the worm, by which the finished spirit is discharged into a small covered vessel, *r*, which contains an alcoholometer, *s*, to indicate the strength of the spirit.

The fermenting molasses are so viscous, when they are treated in such a way as to mark only 8° of the areometer, that at some periods the mixture intumesces, so as to overflow the fermenting tuns, unless the latter be very large. To obviate this, some soft soap is added, which being partly decomposed by the little excess of acid contained in the liquid, the oily portion forms a layer which destroys the homogeneousness of the sirupy effervescence, and disposes the bubbles of carbonic acid to burst and pass off without much rising in the liquid. Fermentation is known to be finished when the action, after having been regularly increasing, ceases suddenly, and the temperature subsides; another sign by which a good fermentation is distinguished, is the falling in of the head, and the diminution of specific gravity, from 8° to 1°.

If the liquid, after attenuation, be not immediately distilled, it is necessary to cool it down rapidly, to prevent its being converted into acetic acid. This is done either by passing cold water through a coiled pipe in the fermenting tun, or by emptying the whole into sulphured tubs, which resist the further action of any fermentation. Of these two, the worm is preferable, as in a slow fermentation the transmission of hot water through this pipe would revive it; and when the temperature of the liquid becomes higher than what it should be, from a too rapid fermentation, it is equally opposed by pouring cold water through the worm. LAUGIER'S apparatus is best adapted for the distillation of the fermented liquor of molasses.

The quantity of spirit obtained from molasses when fermented at 14°, is less than when the mash is made to mark 8°; but considering the advantage of obtaining the alkaline matter there is less evaporation, and, consequently, less fuel consumed. A method has been lately introduced by DUBRUNFAUT, by which the attenuation is made at 8°, and the saline matter obtained without much extra fuel. One part of this process is to employ the spent liquor after distillation, for bringing a second portion of molasses to 8° of the areometer; this liquor has no injurious effect upon the fermentation, and offers the advantage of having double the quantity of salts in the same bulk of liquid.

This liquid he introduced into a steam boiler instead of water, for the purpose of generating steam to heat the liquid for distillation, and the apparatus. Finally, the evaporation is finished in three pans or boilers, which are partly heated by the waste caloric from a reverberatory furnace at the end, wherein the saline mass is torrefied. The degree of strength which the liquid has, before it is run into the furnace, is 32°. One thousand kilogrammes of molasses afford from one hundred to one hundred and forty kilogrammes of saline matter, marking 50° to 55° on the alkalimeter.

POTATO SPIRIT.—Potatoes afford a considerable quantity of alcohol; and of late years the manufacture has been extensively conducted in France. There are two methods practised: in the first, the starch of the potato is fermented without any previous preparation, and in the second, the starch is converted into sugar by sulphuric acid. If a quantity of starch, no matter whether obtained from wheat or potatoes, be boiled with water acidulated with sulphuric acid, incessantly, during a few hours, occasionally adding water as it evaporates, to preserve perfect fluidity; then saturating with lime—continuing the boiling, after separating the sulphate of lime, until the solution be concentrated—a dark sirupy liquid is obtained, which, on cooling, affords abundance of sugar in crystals. This sugar certainly differs, in some respects, from common sugar; it is not quite so sweet, nor so soluble in water; it crystallizes differently, fuses at a much lower heat, and its solution ferments without the addition of yeast. It has been found that, during the whole process of its formation, not a bubble of gas is discharged; that the sulphuric acid remains unchanged, and that the contact of air is unnecessary. These facts afford additional proof that starch and sugar are the same in composition, and that the conversion is effected by some unknown agency of the sulphuric acid in altering the mode of combination in which the carbon, oxygen, and hydrogen are held together. One hundred parts of starch produce about one hundred and ten parts of sugar, which is converted by fermentation into alcohol. The advantages afforded by converting potatoes to this use, are, that they are cheap, and afford a good spirit, while the residuum of the distillation is good food for cattle; grain is economized, and less yeast is consumed.

To obtain spirit according to the first process, the potatoes are to be well steamed for an hour, and then bruised between two cylinders of wood or sandstone Ground malt is to be mixed in a keeve with warm water, in quantity sufficient to give the consistence of thin pap, and the potato paste is then added, the whole well stirred with a proper quantity of water until no lumps remain. The stirring is to be renewed at intervals, until the mixture is cold. Natural yeast of beer, or that made artificially from rye, is introduced, but in less quantity than would be required for corn, since potatoes ferment more easily. Experience has proved that the addition of red beetroot or carrots to the potatoes and malt, affords spirit of a better flavor, and in larger quantity. When the fermentation has been pushed to its utmost, the whole matter, both liquor and sediment, is to be introduced into the still, and distilled as in any other case, taking proper precautions to prevent burning.

The process recommended by M. SIEMEN, and now applied in Denmark, is to heat three or four tons of potatoes in steam, a little above 212°, then to mash them well by the rotatory motion of an iron cross in the same vessel wherein they are steamed, and to add hot water, alkalized with a pound and a quarter of caustic potassa. All the mucilage which, in the boiled potatoes, commonly remains insoluble, is by the addition of the alkali converted into a starch, which easily passes through the sieve, leaving the thin skin of the potato. The water is to be in such quantity as to form a thin paste; this being quickly cooled, yeast is added, and the process conducted in the usual manner. It is said, that by this method the quantity of spirit from a given weight of potatoes is greatly increased. Fifty hectolitres, thirty litres—137·64 imperial bushels—of potatoes, along with eight hectolitres—22·12 imperial bushels—of ground malt, yield nine hectolitres—198 imperial gallons—of spirit. CADET states that eight hundred pounds of potatoes will afford thirty pounds of spirit, which at that time he calculated to cost the distiller thirty-six francs, and to sell for forty-eight.

The process for procuring alcohol from potato sugar needs not be particularly described. The sugar being once obtained from potato starch, it is easy to conduct the fermentation. During the conversion of the starch into sugar, a few drops of a solution of iodine in alcohol is frequently added to a small portion of the liquor, to see if the blue iodide of starch is formed; this reaction manifests itself as long as any undecomposed starch remains. From fifty kilogrammes—110·31 pounds avoirdupois—of potato starch, converted into sugar by sulphuric acid, are obtained from twenty to twenty-five litres—4·4 to 5·5 imperial gallons—of alcohol, at 0·935.

VAUQUELIN, who examined forty-seven kinds of potatoes, says that the quantity of starch in one hundred parts varies from twelve to twenty-four parts—the average result was found to be from seventeen to nineteen per cent. According to WUNRICH, starch requires but one or two per cent. of sulphuric acid to convert it into sugar, if the heat applied be a few degrees above 212°; and two or three hours are then sufficient to crystallize it. He applies steam heat in wooden vessels.

During the last runnings of the fermented starch of potato, when under distillation, an oil is obtained, which was examined by PELLETAN, and which he supposed to resemble the oil procurable from corn spirit. The two oils are, however, materially different.

The yeast thrown up by potatoes during fermentation, even with one-fifth of their weight of barley, possesses but little energy, and is, therefore, not used in attenuating the potato wash.

In the experiments made under the personal inspection of Professor OERSTED at Copenhagen, from sixteen and a half to seventeen quarts of spirit, at 50° of Tralles' alcoholometer, were obtained from a ton of potatoes, making a fair allowance for that portion of the product due to the malt used in the maceration. This spirit is stated to have had a good flavor, though the produce was inferior to that obtained by the French chemists. MULLER asserts that an apparatus on SIEMEN'S principle, the expense of which is about two hundred and fifty Prussian dollars, is capable of producing fifty per cent. more spirit from potatoes than the apparatus generally used in Germany, calculating from the price and produce of potatoes and rye in 1820. He further adds, that a hundred-weight of the former converted into spirit produces a profit of from five hundred to six hundred rix-dollars, while the same space of ground that produced it, if sown with rye, would not give more than from ten to twelve rix-dollars.

About the year 1832, a gentleman visited the distillery of Messrs. CALDER at Eyemouth, in Berwickshire, and found that they had worked for some short time from potatoes. He considered the spirit—which had the flavor of hollands—to be pure and good; and although it was affirmed that no grain or malt had been used, he strongly suspected the contrary. The fermentation was described as beautiful, the head rising seven or eight feet like clouds of cotton; and when beaten down to the surface of the worts, it rose again in the same majestic manner. The gravity worked at was 40°, and the attenuation was good. The potatoes were ground in a mill, like a common pepper-mill in shape, but made of sheet-iron perforated like a grater. The pulp, thus produced, was mashed in the keeve with boiling water, and the extract ran off quite pure, and freely. A sperge, or small worts of about 20° gravity, was obliged to be used, otherwise the worts at the noticed gravity of 40° could not be got off; the produce was good, as there was no deficiency. The spirit sent to the London market, when called grain spirit in the permits, was highly prized; when this error was corrected, and the product was denominated spirit distilled from potatoes, the price fell, and it was not so much in vogue. About the same time, Mr. JAMIESON of Fairfield, near Enniscorthy, commenced distilling from potatoes. They were sliced, dried on a corn-kiln, ground to flour, mixed in certain proportions with grain, and mashed in the ordinary manner. But the manufacture was abandoned, in consequence of the opposition of the peasantry, through fear of a scarcity in the article of food.

From some late experiments, DUBRUNFAUT proposed to brew from the starch of potatoes an excellent beverage resembling French beer, the starch being macerated and fermented with hops. By fermenting the saccharized starch with honey instead of hops, a palatable liquor was made, having all the qualities of Louvaine beer. Potato starch, being free from any peculiar taste, seems capable of receiving flavor in its fermentation from any substance that gives repute to beer, or home-made wines. Dr. HARE, having observed a strong analogy between the saccharine matter of the sweet potato and molasses, or the saccharum of malt, boiled a wort made from the potatoes, of 1060° specific gravity, with a proportionate quantity of hops for the space of two hours. It was then cooled to about 56°, and yeast added. As far as could be judged, the phenomena of the fermentation and the liquor produced, were precisely the same as if malt had been used. The wort was kept in a warm place until the temperature was 85° Fahrenheit, and the fall of the head showed the attenuation to be sufficient; yeast subsequently rose, which was removed by skimming. A further quantity of yeast was precipitated by refrigeration, from which the liquor being decanted, became tolerably fine for new beer, and resembled in flavor ale made from malt. It has been computed that five bushels of potatoes would produce as much wort as three bushels of malt, while the residue, as food for cattle, would be worth half as much as the potatoes.

In the opinion of some—particularly those who have not employed sulphuric acid in saccharifying the starch—the best time to use potatoes in distillation is in spring, when they begin to vegetate. The growth of the buds must be checked, as in the process of malting; and this is easily done by spreading them on a floor, and by subsequent turning, so as to deprive them of as much of their water as possible. When reduced to a pulpy consistence, diluted with boiling water, and drawn off and cooled to a proper temperature, the liquid is then fermented in the same manner as grain worts; and such has been the treatment observed by many who have tried the distillation of potatoes in this country. Sprouted potatoes produce as perfect farina in July as in December, and equal in quantity to what they would have yielded earlier in the season, being, according to Sir JOHN SINCLAIR, about fourteen pounds per hundred-weight.

It has been stated that potato apples give, by proper treatment, as much alcohol as an equal quantity of grapes, when bruised and fermented with one-eighteenth or one-twentieth of their weight of yeast.

From these details on the application of potatoes in the manufacture of spirit, persons may be induced to try experiments that might ultimately prove advantageous. If they proceed by reduction of the farina to a pulpy substance, the operation is simply by boiling; if by the production of starch, it may be mechanically effected at little expense and labor, either by pounding or grating, and elutriation with cold water. In some parts of France, the tuber of the Jerusalem artichoke —*Helianthus tuberosus*—has been used for the purpose of distillation. The wash extracted from this vegetal, when fermented in the ordinary way, is found to yield a very pure and strong spirit, which is said to resemble that obtained from the grape, more than any other substitute that has hitherto been tried.

The root grows luxuriantly almost in every climate, but it does not appear that it has been cultivated much in England, either for the production of spirit or other uses; it might be remunerative in this particular, in producing a medium beverage between genuine French brandy, and the fiery spirit extracted from grain, and sold under the denomination of gin and whisky.

ARRACK, contracted into RACK, is a spiritous liquor from the East Indies. The name is said to signify, in the East, any alcoholic liquor; but that usually bearing this name is *toddy*, a liquid distilled from the juice of the cocoa-nut tree—*cocos nucifera*—procured by incision. In all countries where rice is abundant, an alcohol is drawn from it, called *arrack* or *rack*. Goa and Columbo arrack are always made from toddy; Batavia and Jamaica arrack from molasses and rice, with a little toddy. The Pariah arrack contains *cannabis sativa* and a species of *Datura*, which render it more inebriating and hurtful; it is not, however, certain, whether the Pariah arrack is used generally to imply a sophisticated spirit, or is only applicable to that liquor with which the above ingredients have been compounded.

The process is nearly the same as for making grain spirit. Rice is put into a vat, covered with water, and agitated to cause it to pullulate. A handful is, from time to time, taken from different parts of the vat, and if the half at least has not pullulated the germination is allowed to proceed, or the fermentation may be hastened by adding lukewarm water, and drawing a certain quantity from the top, heating and returning it to the vat, the contents of which are well stirred. Great caution is necessary in the operation, for, if rummaged too quickly, much risk is run of breaking the seed, which would make the rice decay, and thus hinder the fermentation of the rest. If such a thing occurs, the injured grain might be extracted, but this would be attended with so much labor, as compared to the value of the rice, that the whole is rejected by distillers, and sold for the use of cattle. To avoid these mishaps, a man accustomed to the work is employed. He introduces the rake just below the surface of the rice, agitates the water in turning, and stirs gently till he reaches the bottom; the same caution is observed in bringing the rake again to the surface. When the rice is nearly or half germinated, the plug at the under part of the vat is withdrawn to let out the water; the rice is then removed to a room, and heated like the barley in the distillation of the grain spirit. It is submitted to a heat of 59° Fahr., which finishes the germination.

The subsequent operations are the same as those pursued by the brewer. When the rice has sufficiently acquired the vinous fermentation, it is introduced into the alembic or still, like the other substances discussed.

MOREWOOD was favored, by a gentleman many years resident in India, with several curious remarks upon the kind of stills employed, and the methods pursued. When the material for distilling—whether rice, or the simple fermented juice of the *cocos nucifera*—is ready, a hole is dug in the earth, suited to the size of the still to be used; and, on a level with the bottom of this hole, there is an underground communication made for the purpose of feeding the fire with atmospheric air; near the edge of this orifice is a chimney, serving two purposes—for the supply of the fuel, and for the escape of the smoke; a fire of dry wood is first lit, and, when the ground is completely heated, the still is fixed in it, and so bound round with earth, as to prevent the escape of any caloric. When ebullition commences, and the steam begins to ascend, an Indian pours a gentle stream of water upon the head of the still, or on the broad and thin surface of a plate of tin or copper, with a gutter for the water to run off, which is fixed on a pan, with a hole in the bottom, luted to the neck of the still, and serving as a condenser. The extreme cold produced by the evaporation of the water on so broad a surface, occasions the vapor from the still to be immediately condensed, and to flow in a trickling stream into the receiver.

A lady who resided in India thus describes the working of a native still which she had an opportunity of seeing:—The still was simply constructed: round a hole in the earth, a ledge of clay, four inches high, was raised, with an opening half a foot in width, for the purpose of supplying fuel. Upon the clay a large earthen pot was luted; to its mouth was closed with lute the mouth of a second pot; and where they joined, an earthen spout, a few inches long, was inserted, which served to let off the spirit condensed in the upper jar, the latter being kept cool by a person pouring water constantly upon it. In the cottage, or still-house, was a woman employed in cooling the still by pouring water on it from a cocoa-nut shell ladle. The woman said that she sat at her occupation from sunrise to sunset, without scarcely a change of position, while her husband constantly brought toddy for distillation.

Arrack is drunk in Siam; but its consumption, as well as its facture, is confined to the Chinese resident in that country. It is stated that the privilege for its distillation brings to the government fifty-eight thousand pounds per annum, for the whole kingdom. The greater portion of arrack is distilled at Bankok, the capital; and the remainder at thirteen of the principal towns.

A strong kind of arrack, possessing an unpleasant smell, is distilled from palm wine, *et cetera;* this spirit is called *vellipatty;* another sort is known under the name of *talwagen*. The revenue arising from arrack, in Ceylon, is very large; in the land-rents are included the duties on cocoa-nut trees, which exceed those on rice by nearly fifteen thousand pounds annually.

Arrack, from time immemorial, has been a common beverage among the Cingalese, but as yet their method of manufacturing it is rude, indicating a great want of chemical skill.

The still they employ is of earthenware, and of the simplest construction; the subjoined is, on the authority of Morewood, a true representation of the one in general use:—

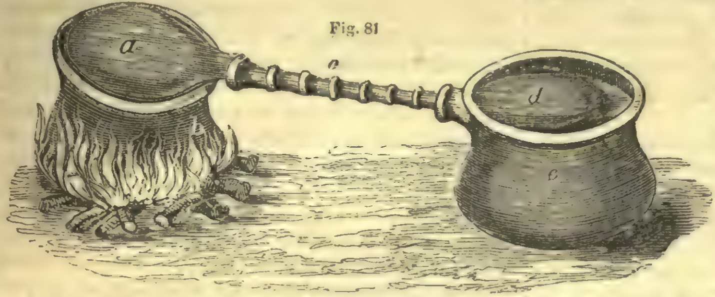


Fig. 81

a, *b*, are the capital and alembic luted together; *d*, *e*, a receiver and refrigerator, of one piece, the former connected with the head by a bamboo, *c*.

Ardent spirit is manufactured in much larger quantities in Java than in any other island in the Indian ocean, which may, no doubt, be accounted for by the great industry of the Dutch, and the celebrity which the Batavian arrack so early acquired under their patronage. According to Sir Thomas Raffles, the annexed is the manner of making it:—About seventy pounds of *ketan*, or glutinous rice, are filled up in a small vat; round this heap one hundred cans of water are poured, and on the top, twenty cans of molasses; after remaining two days in this vat, the ingredients are removed to a larger vat adjoining, when they receive the addition of four hundred cans of water and a hundred of molasses. Thus far the process is carried on in the open air. In a separate vat within doors, forty measures of palm wine, or toddy, are immediately mixed with nine hundred of water, and one hundred and fifty of molasses, both preparations being allowed to remain in this state during two days. The first of these preparations is carried to a still larger vat within doors; and the latter, being contained in one placed above, is poured upon it through a hole bored for the purpose near the bottom. In this state, the entire preparation is allowed to ferment for two days, when it is poured into small earthen jars, containing about twenty cans each, in which it remains for the further period of two days, and is then distilled. The proof of a sufficient fermentation is obtained by placing a lighted candle or taper about six inches above the surface of the liquor in the fermenting vat; if the process be properly advanced, the carbonic acid rises and extinguishes the light. Another mode of apportioning the materials for the making of arrack is,

62 parts molasses,
3 do. toddy,
35 do. rice,

which yield, on distillation, twenty-three and a half parts of proof arrack. The stills are made of copper, and are much like those used in the West Indies; the worms consist of about nine turns of Banca tin. The spirit runs into a vessel under ground, whence it is poured into proper receivers, and is called the third, or common sort of arrack, which by a second distillation in a smaller still, with the addition of some water, becomes the second sort; and by a third operation, is what is called the first sort. To ascertain the strength of the spirit, a small quantity of it is burned in a saucer, and the residuum measured; the difference between the original quantity and the residuum gives the measure of the alcohol lost. The completion of the first sort does not require more than ten days, six hours being sufficient for the original preparation to pass through the first still. The Chinese residents, who conduct the whole of this process, call the third, or common sort, *sichew;* the second, *tanpo;* and the first, *kiji.* The latter two are distinguished as arrack *api.* When cooled, it is poured into large vats in the storehouses, where it remains until put into casks. The making of arrack is distinct from that of sugar, which is manufactured to a great extent in Java. The arrack distillers purchase the molasses from the sugar manufacturers.

A very large quantity of arrack is consumed in the East; seven hundred thousand gallons are annually exported from Ceylon, of which upwards of thirty thousand come to England.

Carrot Spirit.—In the Transactions of the Royal Society of Edinburgh, is a paper by Dr. Hunter and Mr. Hornby, in which they give the details of the process for the production of the above spirit. With the paper was sent a sample of the spirit, and the Society appointed Dr. Black, Dr. Hutton, and Mr. James Russell, to investigate this account, together with the specimen of the spirit, and to report upon the same, which they did as follows:—

The sample of spirit which was sent by Dr. Hunter, of York, to the Royal Society, has been examined, and also the account of the experiment on the fermentation and distillation of carrots, by which the spirit was produced. The experiment was made by Mr. Thomas Hornby, druggist in York, with one ton and eight stones of carrots, which, after being exposed to the air a few days to desiccate, weighed one hundred and sixty stones, and measured forty-two bushels; they were affused with water, topped, and tailed, by which they lost in weight eleven stones, and in measure seven bushels; and being then cut, were boiled with the proportion of twenty-four gallons of water to one-third of the above-mentioned quantity of carrots, until the whole was reduced to a tender pulp, which was done by three hours' boiling. From this pulp the juice was readily extracted by means of a press, and two hundred gallons of juice were produced from the whole quantity.

The juice was reboiled with one pound of hops for five hours, and then cooled to 66° Fahrenheit, and six quarts of yeast being added, it was set to ferment. The strong fermentation lasted forty-eight hours, during which time the heat abated to 58°; twelve gallons of unfermented juice, which had been reserved, were then heated, and added to the liquor, the heat of which was thus raised again to 66°, and the fermentation was renewed for twenty-four hours more, the air of the brewhouse being all this time at 44° and 46°. The liquor was now turned, and continued to work three days from the bung; lastly, it was distilled, and the first distillation was rectified next day without any addition. The produce was twelve gallons of spirit. It resembled the best corn-spirit in flavor, and was proof. The refuse of the carrots weighed forty-eight stones, which, added to the tops and tails, made provision for hogs, besides the wash from the still, which measured one hundred and fourteen gallons.

From the above, Dr. HUNTER draws the annexed comparison between the distillation of carrots and grain:—

Twenty tons of carrots, which will make two hundred gallons of proof spirit, may be bought for £16. Eight quarters of malt, or rather materials for distillation, consisting of malt, wheat, and rye, may be bought for £16, and will also yield two hundred gallons of proof spirit. The refuse from the carrots will be nine hundred and sixty stones, which, at one penny per stone, will sell for £4. The refuse or grains from the malt, *et cetera*, will be sixty-four bushels, each bushel about three stones, which, at one penny per stone, will sell for sixteen shillings. The Doctor, however, supposes that the manufacture of the spirit from carrots may be attended with more expense than that from malt, but imagines that the greater value of the refuse may compensate for that expense, and that the saving of corn for other purposes is an object worthy of attention and of encouragement.

MILK SPIRIT.—The Tartars and Kalmouks prepare a spirit from the milk of mares or cows, which they greatly relish. Twenty-one pounds of milk yield an ounce and a half of an insipid distillate, and forty ounces of spiritous liquor; the latter, when rectified, gives six ounces of alcohol. OSERETSKOWSKY says that skimmed milk, when deprived of its butyraceous portions, neither produces spirit, *per se*, nor by the addition of a ferment. Secondly, milk retaining a portion of its cream, agitated until it commences fermentation, produces alcohol, but in small quantity. Thirdly, the entire milk kept in a close vessel, which by agitation commences fermenting, furnishes more spirit. Nearly the same amount of spirit is procured from the same milk, when a ferment is added to it. Fourthly, milk deprived of the most part of its caseous matter furnishes very little spirit. Fifthly, when the serous part only of the milk is distilled, it affords little spirit. Sixthly, milk which is fermented in a close vessel, and left for some time, loses its acid, and furnishes much more spirit than it would do if distilled immediately. Seventhly, if the heat of the fermented milk be sustained, the alcoholic portion passes into vinegar.

MADDER SPIRIT.—Within the last few years a patent has been taken out in France by M. JULLIEN, for distilling a spirit from the washings of madder, which were previously allowed to run waste. Several madder distilleries are now established in France, and one has been lately erected in Glasgow, by Mr. J. HINSHAW, of the firm of Messrs. ARTHUR and HINSHAW.

To explain the economy of this remarkable process, it may be stated that the madder is imported into this country in the form of a root, which somewhat resembles liquorice, or the stems of heather. To prepare it for the dyer, and especially for dyeing the celebrated turkey red—which has long been a staple business in Glasgow—the root is first roasted, or kiln-dried; it is then ground into a coarse powder by two large cylinders of stone, revolving in a vertical position, like those used for crushing linseed-cake; in this state it is washed and subjected to hydrostatic pressure, to free it from the saccharine and other matters which would injure its dyeing qualities. When properly washed, it is again dried, and submitted to the action of another pair of stone cylinders, until it is reduced to an impalpable powder.

The washings of the madder at the dye-stuff factory of Messrs. ARTHUR and HINSHAW were formerly permitted, as in other establishments, to flow into the nearest canal, or other reservoir of refuse; but now it is carefully preserved, and distilled into a strong spirit, which, although more volatile and less agreeable to the taste than that distilled from malt or raw grain, may perhaps be found equally useful for various manufacturing purposes.

The process of the fabrication is exceedingly simple: mere washing of the madder supersedes the mashing of the grain or malt in common distilleries. The root being dried and ground, as already stated, is mixed in a series of vats with the requisite proportion of cold water, or water at the ordinary temperature. These vats are three feet deep by five or six in diameter. The mixture is effectually rummaged by the workmen with instruments resembling large hoes, the madder being kept in a state of diffusion in the liquid until it is conceived that the saccharine matter is entirely extracted. The liquor is then drawn off by sluices, and the vats being lined with coarse cloth, it percolates through that medium as a filter, leaving the madder behind, to be again carefully collected, dried, and finally ground for the use of the dyer.

When the madder liquor, or worts, is drawn off, it is let into a kind of under-back, from which it is immediately pumped up into a large fermenting tun. Two tons of madder are found in practice to yield two thousand five hundred gallons of liquor, or madder worts, of a density equivalent to 30° by Allan's saccharometer.

The fermenting tun being filled by the produce of several washings, has usually begun to ferment before it receives the liquor from the last washings. It is not a little remarkable, that this fermentation of the madder liquor commences and proceeds spontaneously, without the addition of yeast, or the application of heat. No ferment of any description is added, and the water used throughout the entire process, up to the point of distillation, is at the ordinary temperature. The addition of yeast has been tried, but without any sensible advantage, either in promoting the fermentation, or increasing the ultimate yield of spirits. In consequence, however, of this spontaneous character of the process, the fermentation is slower than usual, averaging from six to eight days to bring the worts to a proper attenuation. This is conceived to be accomplished when the gravity of the worts is reduced from 24° to 12°.

From the fermenting tun the wash is immediately run into the still, and the rest of the operation proceeds as in the distillation of malt or raw grain whisky. The still used is **Stein's** patent, and is somewhat similar to **Coffey's**, but rather more complex in its arrangements, and possessing the undoubted advantage that it may be applied, with equal efficiency, either to the distillation of malt or raw grain whisky. From this still the madder spirit is drawn off at one operation; it may be run weaker or stronger, but is generally taken from the still about 60° to 64° over proof by **Sykes'** hydrometer.

The produce from two tons of madder, yielding, as has been stated, two thousand five hundred gallons of liquor at 30°, is about sixty gallons of spirit.

The madder distillery at Glasgow, to which the preceding details more especially refer, has only been a few months in operation, and, therefore, the ultimate success of the experiment cannot yet be decided. The high duty on spirit in this country places it under a great disadvantage, compared with the French distilleries of the same kind. It turns to account, however, for manufacturing purposes at least, an otherwise useless substance, hitherto lost to the community, and, as a remarkable illustration of manufacturing economy, it certainly ought to succeed.

Another New Source of Spirit.—It is stated that the berries of the *Sorbus Aucuparia* are now used in the North of France for the production of spirit, and the result is said to be equal to the purest distillation from grapes for brandy. The berries, when perfectly ripe, are first exposed to the action of cold in the open air, then put into a wooden vessel, bruised, and boiling water poured on, the menstruum being stirred until it has sunk in temperature to 82° Fahr. A proper quantity of yeast is then added, the whole covered and left to ferment. When the action has terminated, the liquor is put into the still, and drawn over in the usual way. The first running is weak and disagreeable in flavor, but being distilled from very fresh finely-powdered charcoal, in the proportion of eight or nine pounds to forty gallons of weak spirit, a very fine product is obtained. The charcoal should remain in the liquid two or three days before the second distillation.

Having given a full account of the different kinds of spirit, the reader must have perceived how much has still to be accomplished for the guidance of those connected in any way with alcoholic liquors. It is to the resources of Chemistry that one must look for such improvements. The chemist first lighted the distiller's path by his researches on the essential oils which communicate to wines, grain spirit, potato spirit, *et cetera*, their peculiar bouquet, and by a prosecution of his labors he procured these compounds in greater abundance. Such discoveries led to the artificial imitation or formation of the rarer and more costly liquors, as cognacs, genevas, and other beverages which, on account of their high price, are attainable only by the affluent. It is to be regretted, however, that those engaged in manufactures, for the proper management of which there is hourly required an intimate acquaintance with the several reactions of bodies, and the various changes to which they are subject, are so far ignorant of the general properties of even those very substances which are daily passing through their hands, that it is not uncommon to find many who know nothing of the nature of their products beyond the mere name. The consequence of this want of scientific knowledge in the seats of art, and with the owners or conductors of factories, is, that in many instances the most palpable incoherency is shown in the methods adopted; a fact manifested in the inferiority of some of the industrial products of this nation at the Great Exhibition. Successful competition or results, in any fabrication, can only be attained by attentive study; indeed, by making manufacturers students of science. Without chemistry, a process connected therewith, how trivial soever it may be, cannot prosper; and this being admitted, it is surprising and even deplorable that the archives of science are not oftener consulted by persons daily witnessing the triumphs that emanate from this prolific source; instead of doing so, many assert that chemistry is of no use to them—that they look to *practice* for improvements and advantages—in fact, they are ready to reject it *in toto*, as being nothing better than a visionary speculation of some few dreaming theorists. No one will, it is presumed, impugn the fact, that what is often attributed to practice is really the result of a long investigation; and further, that the advances made at a considerable, or rather incredible sacrifice of capital and labor, in the course of centuries, may be superseded by purely theoretical studies in a single day. In truth, most of those who speak disparagingly of scientific and theoretical research are, though strangely inconsistent, ready to acknowledge the benefits conferred upon many branches of industry by chemical discoveries.

From scientific inquiries, even the distillers and rectifiers of spiritous liquors have gathered a rich harvest of experience, inasmuch as they have been made better acquainted with the nature of their operations, and more qualified to procure artificially any beverage almost instantaneously. But many of this class, much to the detriment of their business character, pass by chemistry entirely; the consequence of which is, that in the fabrication of artificial liquors a most absurd course is often adopted, and mixtures used, in favor of which there is neither the evidence of reason nor of common sense.

Alcoholometry.—This is the process for ascertaining the centesimal quantity of anhydrous alcohol in a spiritous liquid. It is invariably accomplished by determining the specific gravity of the liquid, but then it is absolutely necessary that only alcohol and water should be present. The quantity of alcohol in spirit containing much volatile oil or saccharine matter, *et cetera*, cannot, therefore, be at once found by their specific gravity.

With the view of being able to calculate the absolute alcohol included in a spiritous liquid from its specific gravity, it was deemed advisable to mix anhydrous alcohol and water in the different proportions, and by experiments, to establish, with certainty, the specific gravity of these mixtures. Such experiments have been gone through at distinct periods; the most accurate and complete were those performed by **Gilpin**. From **Gilpin's** conclusions, aided by results of his own, **Tralles** constructed the tables appended.

The per centage of absolute alcohol may be stated by one of two methods; namely, by weight or volume. Liquors being vended by measure and not by weight, the centesimal amount by volume is usually preferred. But as the bulk of liquids generally, and particularly that of alcohol, increases by heat, it is necessary that their reputed richness should have reference to some normal temperature; this standard, as fixed by TRALLES in the construction of his tables, is 60° Fahr.

By weight the per cent. remains the same at all temperatures, while the per cent. by volume varies with the temperature of the liquid; and this entails the necessity of having the sample, in the course of being tested, reduced to the standard degree of the table by calculation or otherwise. In the subjoined, water at its maximum density is taken as the standard for specific gravity, and is put as 1·000, which, at 60° Fahr., equals ·9991.

TABLE I.

Per cent. of alcohol, by volume.	Spec. grav. of the liquid at 60°.	Difference of the spec. gravs.	Per cent. of alcohol, by volume	Spec. grav. of the liquid at 60°.	Difference of the spec. gravs.
0	0·9991		51	0·9315	20
1	9976	15	52	9295	20
2	9961	15	53	9275	20
3	9947	14	54	9254	21
4	9933	14	55	9234	20
5	9919	14	56	9213	21
6	9906	13	57	9192	21
7	9893	13	58	9170	22
8	9881	12	59	9148	22
9	9869	12	60	9126	22
10	9857	12	61	9104	22
11	9845	12	62	9082	22
12	9834	11	63	9059	23
13	9823	11	64	9036	23
14	9812	11	65	9013	23
15	9802	10	66	8989	24
16	9791	11	67	8965	24
17	9781	10	68	8941	24
18	9771	10	69	8917	24
19	9761	10	70	8892	25
20	9751	10	71	8807	25
21	9741	10	72	8842	25
22	9731	10	73	8817	25
23	9720	11	74	8791	26
24	9710	10	75	8765	26
25	9700	10	76	8739	26
26	9689	11	77	8712	27
27	9679	10	78	8685	27
28	9668	11	79	8658	27
29	9657	11	80	8631	27
30	9646	11	81	8603	28
31	9634	12	82	8575	28
32	9622	12	83	8547	28
33	9609	13	84	8518	29
34	9596	13	85	8488	30
35	9583	13	86	8458	30
36	9570	13	87	8428	30
37	9556	14	88	8397	31
38	9541	15	89	8365	32
39	9526	15	90	8332	33
40	9510	16	91	8299	33
41	9494	16	92	8265	34
42	9478	16	93	8230	35
43	9461	17	94	8194	36
44	9444	17	95	8157	37
45	9427	17	96	8118	39
46	9309	18	97	8077	41
47	9391	18	98	8034	43
48	9373	18	99	7988	46
49	9354	19	100	7939	49
50	9335	19			

The third column of this table exhibits the differences of the specific gravities, in order to facilitate the calculation of fractions of per centage for specific gravities intermediate between those stated in the table—the difference in the densities, as given in the third column, becoming the denominator of the fraction, and the variation between the next and greatest specific gravity in the table and that of the liquid in question forming the numerator. To illustrate this method of calculation by an example, let it be supposed that the specific gravity of a liquid was found to be ·9260 at 60° Fahr., which numbers, according to the table, would indicate a per centage of alcohol between fifty-three and fifty-four, or fifty-three and a fraction whose numerator is the difference between ·9275, the specific gravity of an alcohol fifty-three per cent., and ·9260, which difference equals 15; this number forms the numerator of the fraction, whose denominator is the difference between the specific gravities of the liquids containing fifty-three and fifty-four per cent. of alcohol, and which in the foregoing table is 21; hence the value of the liquid, specific gravity ·9260, is $53\frac{15}{21}$, or 53·71 per cent.

The content, by weight, of alcohol in a liquid, the centesimal value of which per volume has been found, is ascertained by a simple calculation. This operation is done by multiplying the content per volume of alcohol into the specific gravity of absolute alcohol, and dividing the product by the specific gravity of the liquid. An example will aid the reader in comprehending the manner of performing the work:—Suppose an alcohol of fifty per cent. by volume, whose density, according to the preceding table, is ·9335. Absolute alcohol in the table is ·7939, and this multiplied by 50, and the product divided by ·9335, gives the per centage by weight, thus:—

$$\cdot7939 \times 50 = 39\cdot6950 \div \cdot9335 = 42\cdot5227 \text{ per cent.}$$

It necessarily happens that alcoholic liquors are seldom at the very degree of the thermometer at which the preceding table has been drawn up, and as it is difficult to bring the sample to mark 60° Fahr., TRALLES, for the purpose of surmounting this obstacle, constructed another table, wherein the volume of alcohol is given corresponding with the temperature of the liquid at the time of the experiment.

TABLE II.

Per cent., by volume, of absolute alcohol.	Spec. grav. of the liquid at 60°.	Increase of spec. grav. at the indicated temperature *below* 60°.					
		+ 55°	50°	45°	40°	35°	30°
0	0·9991	4	7	9	9	9	7
5	9919	4	7	9	10	10	9
10	9857	5	9	12	14	15	15
15	9802	6	12	17	21	23	25
20	9751	8	16	23	29	35	39
25	9700	10	21	31	39	48	56
30	9646	13	26	39	51	62	73
35	9583	16	31	46	61	75	89
40	9510	18	35	52	70	87	103
45	9427	19	39	57	76	94	112
50	9355	20	40	60	80	99	118
55	9234	21	42	63	84	104	124
60	9126	22	43	65	86	107	127
65	9013	22	45	67	88	109	130
70	8892	22	45	68	90	112	133
75	8765	23	46	68	91	113	135
80	8631	23	47	70	92	115	137
85	8488	23	47	70	93	116	139
90	8332	24	48	71	94	117	140

TABLE II.—Concluded.

Per cent., by volume, of absolute alcohol.	Spec. grav. of the liquid at 60°.	Decrease of spec. grav. at the indicated temperature *above* 60°.							
		65°	70°	75°	80°	85°	90°	95°	100°
0	0·9991	1	11	17	24	32	40	50	60
5	9919	1	11	18	25	33	42	51	62
10	9857	6	13	20	29	37	47	57	68
15	9802	7	15	25	34	44	55	67	79
20	9751	9	19	30	41	53	66	79	93
25	9700	11	24	36	50	63	78	93	109
30	9646	14	28	43	59	75	91	108	125
35	9583	17	33	50	68	86	104	122	141
40	9510	18	37	56	75	94	114	136	154
45	9427	20	40	60	80	101	122	143	154
50	9335	21	42	63	84	106	128	150	173
55	9234	22	43	65	87	109	132	155	178
60	9126	22	44	67	90	113	136	159	183
65	9013	22	45	68	92	115	138	162	187
70	8892	23	46	69	93	117	141	165	190
75	8765	23	46	70	94	119	143	167	192
80	8631	23	47	71	96	120	144	169	194
85	8488	24	48	72	96	121	145	170	195
90	8332	24	48	72	97	121	146	171	196

A further objection to these tables is, that the specific gravity of the mixtures of alcohol and water at elevated or reduced temperatures is not the *real* but the *apparent* density. The cause of this discrepancy is, that the vessels of glass or copper in which the liquids are weighed are liable to expand or contract with change of temperature, so that the specific gravity of the liquid obtained in this way is only what results from the difference of the expansion of the liquid and of the vessel.

TRALLES constructed a third table, in order that the per centage by volume in an alcoholic liquid might be ascertained from the more uniform arrangement of the numbers denoting the specific gravities.

In Table III. the densities are given of the several mixtures from 30° to 85°, as ascertained by a glass instrument; but these numbers, by the aid of the allowance, as seen in Table IV., can be made to correspond with the indications of a brass alcoholometer.

TABLE III.

Per cent. of alcohol, by volume.	Specific gravity of the liquid, ascertained by glass instruments, at the indicated temperatures.											
	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
0	·9994	·9997	·9997	·9998	·9997	·9994	·9991	·9987	·9981	·9976	·9970	·9962
5	9924	9926	9926	9925	9925	9922	9919	9915	9909	9903	9897	9889
10	9868	9869	9868	9867	9865	9861	9857	9852	9845	9839	9831	9823
15	9823	9822	9820	9817	9813	9807	9802	9796	9788	9779	9771	9761
20	9786	9782	9777	9772	9766	9759	9751	9743	9733	9723	9713	9701
25	9752	9745	9737	9729	9720	9709	9700	9690	9678	9666	9653	9640
30	9715	9705	9694	9683	9671	9658	9646	9633	9619	9605	9590	9574
35	9668	9655	9641	9627	9612	9598	9583	9567	9551	9535	9518	9500
40	9609	9594	9577	9560	9544	9527	9510	9493	9474	9456	9438	9419
45	9555	9518	9500	9482	9464	9445	9427	9408	9388	9369	9359	9329
50	9449	9431	9413	9393	9374	9354	9335	9315	9294	9274	9253	9232
55	9354	9335	9316	9295	9275	9254	9234	9213	9192	9171	9250	9128
60	9249	9230	9210	9189	9168	9147	9126	9105	9083	9061	9039	9016
65	9140	9120	9099	9078	9056	9034	9013	8992	8969	8947	8924	8901
70	9021	9001	8980	8958	8936	8913	8892	8870	8847	8825	8801	8778
75	8896	8875	8854	8832	8810	8787	8765	8743	8720	8697	8673	8649
80	8764	8743	8721	8699	8676	8653	8631	8609	8585	8562	8538	8514
85	8623	8601	8579	8556	8533	8510	8488	8465	8441	8418	8394	8370
90	8469	8446	8423	8401	8379	8355	8332	8309	8285	8262	8238	8214

TABLE IV.

To be subtracted.						To be added.					
30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
·0005	·0004	·0003	·0002	·0002	·0001	—	·0001	·0002	·0002	·0003	·0004

The necessity for using Table IV. arises from the discrepancy in the contraction or expansion of glass or brass at different temperatures, occasioning variation in the density; hence these numbers must be added or subtracted, as directed, according to the temperature, when a brass instrument is employed.

It occurs that liquids are tested whose temperature and specific gravity are intermediate between those instanced in the preceding table, and in this case the corresponding content of alcohol must be found by an inconvenient method of calculation. To give an example:—Let it be supposed that the specific gravity of an alcoholic solution has been found by experiment to be ·9320 at a temperature of 72° Fahr. In the column under 70°, the specific gravity ·9388 is that which is next over the above number, and in the column under 75° the gravity nearest to it is ·9369, both of which exceed ·9320—the former by ·0068, and the latter by ·0049. The difference between these two numbers is ·0019, which is the variation for 5°, or between 70° and 75°, and by dividing by 5, the quotient is $\frac{\cdot 0019}{5}$, the difference for each degree. As the temperature of the liquid under examination is 72°, or 2° over 70°, it is necessary to reduce the specific gravity to what it would indicate were the liquid at 70°, by adding a multiple of $\frac{\cdot 0019}{5}$ by 2, or $\frac{\cdot 0038}{5} = \cdot 0007\frac{3}{5}$ to the specific gravity obtained—·9320—which would make it $\cdot 9327\frac{3}{5}$, or, omitting fractions, ·9327. By referring to the table, will be seen in the horizontal column opposite 45 per cent. of alcohol, and under 70°, the specific gravity

·9388, and in the same column, in a line with 50 per cent. of spirit, ·9294, whose difference from the foregoing is ·0094; thus the variation in gravity at the same temperature, for 5 per cent. of alcohol, is ·0094. In like manner, the difference of ·9388 and ·9327, the reduced gravity for the liquid specified, is ·0061; and since 5 per cent. of spirit has been shown to correspond with ·0094, it is found, by simple proportion, that ·0061 will be equivalent to 3·24 per cent., and this, added to 45 per cent., the spirit in the liquid of gravity next preceding that which is supposed to be ascertained, gives 48·24 as the per centage by volume of alcohol. Numerically—

$$·9388 - ·9320 = ·0068, \text{ and}$$
$$·9369 - ·9320 = ·0049.$$

By subtracting the lesser of these from the greater, *videlicet*, $·0068 - ·0049 = ·0019$, the difference for the 5° between 70° and 75° Fahr., giving for each degree $\frac{·0019}{5}$; and to reduce the corresponding gravity of the liquid at 72° to that of 70°, there must be added to it $\frac{·0019}{5} \times 2\,(= 72 - 70) = \frac{·0038}{5} = ·0007\frac{3}{5}$; and thus one obtains $·9320 + ·0007\frac{3}{5} = ·9327\frac{3}{5}$, or, omitting fractions, ·9327. Again,

$$·9388 - ·9294 = ·0094, \text{ and}$$
$$·9388 - ·9327 = ·0061.$$

And since the former indicates a difference of 5 per cent. in the amount of alcohol, at the same temperature, the equivalent for ·0061 under similar circumstances is obtained by simple proportion, *exempli gratia:*

As 94 : 5 :: 61 : 3·24, which, when added to 45, gives 48·24, the content per cent. by volume of alcohol in the liquid. From all the tables in the foregoing for the determination of the volume of alcohol in a liquid, at whatever temperature it may stand, it is seen that reference is always had to the per centage at the normal temperature of 60° Fahr. Hence, in examining an alcoholic liquid for its true content of pure alcohol, the heat must be diminished to 60°, or else the temperature noted at the time of experiment, and then by calculation reduced to 60°; or the content of alcohol at 60° may be found as in Table II., where the specific gravity at the different temperatures is in inverse proportion to the volume of alcohol.

To avoid this calculation, **Tralles** calculated another table, which gives the content in volume of absolute alcohol in a liquid, reference being had to the bulk of the liquid at the temperature at which it is measured.

For the prevention of error, it is absolutely necessary to determine the specific gravity of the liquid at the same degree at which it stands when measured; a glass instrument should be employed.

TABLE V.

To ascertain at any temperature, from the specific gravity, the quantity of absolute alcohol in a liquid expressed in volume centesimally, at the indicated temperature.

Per cent. of absolute alcohol in the liquid as measured.	Specific gravity of the liquid, ascertained by glass instruments, at the indicated temperatures.											
	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
0	0·9994	·9997	·9997	·9998	·9997	·9994	·9991	·9987	·9981	·9976	·9970	·9962
5	9924	9926	9926	9926	9925	9922	9919	9915	9909	9903	9897	9889
10	9868	9869	9868	9867	9865	9861	9857	9852	9845	9839	9831	9823
15	9823	9822	9820	9817	9813	9807	9802	9796	9788	9779	9771	9761
20	9786	9782	9777	9772	9766	9759	9751	9743	9733	9722	9711	9700
25	9753	9746	9738	9729	9720	9709	9700	9690	9678	9665	9652	9638
30	9717	9707	9695	9684	9672	9659	9646	9632	9618	9603	9588	9572
35	9671	9658	9644	9629	9614	9599	9583	9566	9549	9532	9514	9495
40	9615	9598	9581	9563	9546	9528	9510	9491	9472	9452	9433	9412
45	9544	9525	9506	9486	9467	9447	9427	9406	9385	9364	9342	9320
50	9460	9440	9420	9399	9378	9356	9335	9313	9290	9267	9244	9221
55	9368	9347	9325	9302	9279	9256	9234	9211	9187	9163	9139	9114
60	9267	9245	9222	9198	9174	9150	9126	9102	9076	9051	9026	9000
65	9162	9138	9113	9088	9063	9038	9013	8988	8962	8936	8909	8882
70	9046	9021	8996	8970	8944	8917	8892	8866	8839	8812	8784	8756
75	8925	8890	8873	8847	8820	8792	8765	8738	8710	8681	8652	8622
80	8798	8771	8744	8716	8688	8659	8631	8602	8573	8544	8514	8483
85	8663	8635	8606	8577	8547	8517	8488	8458	8427	8396	8365	8333
90	8517	8486	8455	8425	8395	8363	8332	8300	8268	8236	8204	8171

TABLE VI.

To be added.						To be subtracted.					
30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
·0005	·0004	·0003	·0002	·0002	·0001	—	·0001	·0002	·0002	·0003	·0004

For the reasons assigned under Tables III. and IV., the numbers in Table VI. must be added or subtracted, as may be deemed necessary, to or from the specific gravities given in Table V., according to the temperature.

From the above tables, the true content of alcohol in a liquor, or *its richness*, may be ascertained by the specific gravity.

It will be as well to consider here the plan pursued for ascertaining with accuracy the specific gravity of the various liquids. Invariably, the density is found by one of two methods—either by actually weighing a portion of the liquor in an accurate specific gravity bottle, or by hydrometer.

The latter is better adapted, as it affords a more expeditious means of finding the density in practice. Various hydrometers are employed, the principal ones being Beaumé's, Sykes', and Dicas', all of which have corresponding tables to indicate the quantities of alcohol according to the gravity. It being thought more convenient and simple to have an instrument which would indicate at once the content of alcohol, one was formed, partly on the plan of the hydrometer, to which the term *alcoholometer* has been applied; it may be made either of glass or brass. **Tralles**, in constructing one of these instruments, has drawn up the annexed alcoholometric table for guidance, which shows, from the portion of the stem immersed in the liquor, the content of alcohol at 60° Fahr.

Table VII.

Per cent. alcohol, by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating per cent.	Per cent. alcohol, by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating per cent.
0	9		51	735	23
1	24	15	52	758	23
2	39	15	53	782	24
3	54	15	54	806	24
4	68	14	55	830	24
5	82	14	56	854	24
6	95	13	57	879	25
7	108	13	58	905	26
8	121	13	59	931	26
9	133	12	60	957	26
10	145	12	61	984	27
11	157	12	62	1011	27
12	169	12	63	1039	28
13	180	11	64	1067	28
14	191	11	65	1096	29
15	202	11	66	1125	29
16	213	11	67	1154	29
17	224	11	68	1184	30
18	235	11	69	1215	31
19	245	10	70	1246	31
20	256	10	71	1278	32
21	266	10	72	1310	32
22	277	11	73	1342	32
23	288	11	74	1375	33
24	299	11	75	1409	34
25	310	11	76	1443	34
26	321	11	77	1478	35
27	332	11	78	1514	36
28	344	12	79	1550	36
29	355	11	80	1587	37
30	367	12	81	1624	37
31	380	13	82	1662	38
32	393	13	83	1701	39
33	407	14	84	1740	39
34	420	13	85	1781	41
35	434	14	86	1823	42
36	449	15	87	1866	43
37	465	16	88	1910	44
38	481	16	89	1955	45
39	498	17	90	2002	47
40	515	17	91	2050	48
41	533	18	92	2099	49
42	551	18	93	2150	51
43	569	18	94	2203	53
44	588	19	95	2259	56
45	608	20	96	2318	59
46	628	20	97	2380	62
47	648	20	98	2447	67
48	669	21	99	2519	72
49	690	21	100	2597	78
50	712	22			

In the practical application of the preceding table, when graduating the alcoholometer, it is requisite to have two liquids of a standard strength and temperature.

Distilled water may be one of these, and the other any alcoholic liquor, the per centage of which has been precisely determined, but it is necessary that both should be at 60°. The level at which the instrument stands in each should be scratched on the stem, and the intermediate space accurately divided according to the strength of the liquid. If the alcoholic liquor be forty-nine per cent., and the distance between the point to which the instrument immerses in this liquid and water be divided into $690 - 9 = 681$ equal parts, the addition of twenty-two such parts will indicate the point for fifty per cent., and twenty-three more for fifty-one per cent., and so on, as is seen in the third column in the table. By adding nine such divisions below zero, or the water-level mark, the point is attained from which the numbers in the second column in the table are calculated for each succeeding per cent. of spirit.

In graduating the scale, it would perhaps be more convenient to have two instruments; one to have indications denoting a per centage, say, from one to eighty, and the other from the latter up to pure alcohol. For this end it would, however, be absolutely necessary to adjust the instrument having the higher indications, with two liquids at the normal degree of temperature of the preceding, whose per centage of alcohol should be eighty and a hundred; then, to observe the points to which it sinks in these, and divide the intermediate space into measures corresponding with those in the table.

In constructing one of these alcoholometers, it is necessary to have the stem as uniform as possible, but tubes varying between one-thirtieth or one-twentieth of the diameter may be used. When this alcoholometer is employed, the temperature of the liquid must be at 60°, else the results will be incorrect; for if the degree should differ from the above, the centesimal amount of alcohol cannot be ascertained by taking the specific gravity corresponding with the spirit indicated by the alcoholometer, and, therefore, the true per centage is calculated from this gravity in the usual way, by Tables III. or IV., as in the foregoing.

To dispense with the trouble of such a calculation, **Tralles** devised another table, by which the *real* per centage of alcohol is found in liquids of different temperatures, from the results exhibited by the instrument. This table is given below, Table VIII., and corresponds with Table III. in the preceding.

The numbers in the vertical columns under the temperatures, are the observed degrees of the alcoholometer, and indicate the per centage of the absolute alcohol by volume. If an alcoholic liquid at a temperature of 75° be found to contain 62·9 per cent. by volume, by reference to the table its true per centage at 60° is 60.

Tables IX. and X. following, give the richness per cent. by volume of the liquid at the temperature it possesses when tested. They correspond with Table V. in the preceding, and, like that, it is necessary that the solution should be tested at exactly the same temperature at which it is measured. Table IX. is for a glass, and Table X. for a brass alcoholometer.

TABLE VIII.

To find the true per centage of absolute alcohol by volume, in a liquid at 60°, from the observed per centage indicated by a glass alcoholometer at any other temperature.

30°	35°	40°	45°	50°	55°	60°	60°	65°	70°	75°	80°	85°
— 0·2	— 0·4	— 0·4	— 0·5	— 0·4	— 0·2	0	0	+ 0·2	+ 0·6	+ 1·0	+ 1·4	+ 1·9
+ 4·6	+ 4·5	+ 4·5	+ 4·5	+ 4·6	+ 4·8	5	5	5·3	5·8	6·2	6·7	7·3
9·1	9·0	9·1	9·2	9·3	9·7	10	10	10·4	11·0	11·6	12·3	13·0
13·0	13·1	13·3	13·5	13·9	14·5	15	15	15·6	16·3	17·1	18·0	19·0
16·5	16·9	17·4	17·8	18·5	19·2	20	20	20·8	21·8	22·8	23·8	24·9
19·9	20·6	21·4	22.2	23·0	24·1	25	25	25·9	27·0	28·2	29·4	30·5
23·5	24·5	25·7	26·6	27·7	28·8	30	30	31·1	32·2	33·4	34·5	35·7
28·0	29·2	30·4	31·6	32·7	33·8	35	35	36·2	37·3	38·4	39·5	40·6
33·0	34·2	35·4	36·7	37·8	39·0	40	40	41·1	42·2	43·3	44·3	45·4
38·4	39·6	40·7	41·8	42·9	43·9	45	45	46·1	47·1	48·2	49·2	50·3
43·7	44·7	45·8	46·9	47·9	49·0	50	50	51·0	52·0	53·0	54·0	55·1
49·0	50·0	51·0	52·0	53·0	54·0	55	55	54 9	56·9	57·9	58·9	59·9
54·2	55·2	56·2	57·1	58·1	59·0	60	60	60·9	61·9	62·9	63·8	64·9
59·4	60·3	61·2	62·2	63·1	64·0	65	65	65·9	66·8	67·7	68·6	69·6
64·6	65·5	66·4	67·3	68·2	69·1	70	70	70·8	71·7	72·6	73·5	74·5
69·8	70·7	71·5	72·4	73·3	74·2	75	75	75·8	76·7	77·6	78·4	79·3
75·0	75·8	76·6	77·5	78·4	79·2	80	80	80·8	81·7	82·4	83·2	84·1
80·3	81·1	81·8	82·6	83·5	84·3	85	85	85·7	86·5	87·3	88·0	88·8
85·6	86·4	87·1	87·9	88·6	89·3	90	90	90·7	91·4	92·0	92·7	93·4

TABLE IX.

To find the true per centage of absolute alcohol by volume, in a liquid of any temperature, from the observed per centage indicated by the glass alcoholometer at the same temperature.

True per cent. of alcohol by volume, at 60° Fahr.	Observed per cent. indicated by the glass alcoholometer.										
	30°	35°	40°	45°	50°	55°	65°	70°	75°	80°	85°
0	— 0·2	— 0·4	— 0·4	— 0·5	— 0·4	— 0·2	+ 0·2	+ 0·6	+ 1·0	+ 1·4	+ 1·9
5	+ 4·6	+ 4·5	+ 4·5	+ 4·5	+ 4·6	+ 4·8	5·3	5·8	6·2	6·7	7·3
10	9·1	9·0	9·1	9·2	9·3	9·7	10·4	11·0	11·6	12·3	13·0
15	13·0	13·1	13·3	13·6	14·1	14·5	15·6	16·3	17·1	18·0	19·0
20	16·5	16·9	17·4	17·9	18·5	19·2	20·8	21·8	22·9	23·9	25·0
25	19·8	20·5	21·3	22·2	23·0	24·1	25·9	27·1	28·3	29·5	30 7
30	23·3	24·3	25·5	26·5	27·6	28·8	31·2	32·3	33·5	34·6	35·9
35	27·7	28·9	30·2	31·4	32·6	33·8	36·3	37·5	38·6	39·7	40·9
40	32·5	33·8	35·1	36·5	37·7	38·9	41·2	42·4	43·5	44·6	45·8
45	37·8	39·1	40·3	41·5	42·7	43·8	46·2	47·3	48·5	49·6	50·8
50	43·1	44·2	45·4	46·6	47·7	48·9	51·1	52·2	53·4	54·5	55·6
55	48·3	49·4	50·5	51·6	52·8	53·9	56·1	57·2	58·3	59·4	60·5
60	53·4	54·5	55·6	56·7	57·8	58·9	61·1	62·2	63·3	64·4	65·5
65	58·4	59·5	60·6	61·7	62·8	63·9	66·0	67·1	68·2	69·3	70·4
70	63·5	64·6	65·7	66·8	67·9	69·0	71·0	72·1	73·2	74·3	75·4
75	68·6	69·7	70·7	71·8	72·9	74·0	76·0	77·1	78·2	79·2	80·3
80	73·7	74·8	75·8	76·9	78·0	79·0	81·0	82·1	83·1	84·1	85·2
85	78·8	79·8	80·9	81·9	83·0	84·0	86·0	87·0	88·0	89·0	90·0
90	84·0	85·1	86·1	87·1	88·1	89.1	91·0	91·9	92·8	93·7	94·6

Thus, if the alcoholometer indicated 59·4 per cent. in a liquid at 80°, the table would give its true per centage—richness—to 55 per cent., that is, 100 volumes of the liquid, at 80°, contain 55 volumes of anhydrous alcohol.

TABLE X.

To find the true per centage of absolute alcohol in a liquid of any temperature, from the observed per centage indicated by a brass alcoholometer at the same temperature.

True per cent. of alcohol by volume.	Observed per cent. indicated by the brass alcoholometer.										
	30°	35°	40°	45°	50°	55°	65°	70°	75°	80°	85°
0	— 0·1	— 0·1	— 0·2	— 0·3	— 0·3	— 0·2	+ 0·2	+ 0·5	+ 0·9	+ 1·2	+ 1·7
5	+ 5·0	+ 4·8	+ 4·7	+ 4·8	+ 4·7	+ 4·8	5·2	5·6	6·1	6·5	7·0
10	9·5	9·4	9·4	9·4	9·5	9·7	10·3	10·8	11·4	12·0	12·6
15	13·5	13·5	13·6	13·7	14·0	14·6	15·5	16·2	17·0	17·7	18·6
20	17·0	17·3	17·7	18·1	18·7	19·3	20·7	21·6	22·7	23·7	24·0
25	20·3	20·9	21·6	22·4	23·3	24·2	25·8	26·9	28·1	29·2	30·3
30	23·8	24·7	25·8	26·8	27·8	28·9	31·1	32·2	33·3	34·4	35·5
35	28·2	29·3	30·4	31·6	32·8	33·9	36·2	37·3	38·4	39·5	40·7
40	32·9	34·1	35·4	36·7	37·9	39·0	41·1	42·2	43·4	44·5	45·6
45	38·1	39·3	40·4	41·6	42·7	43·9	46·1	47·2	48·3	49·4	50·5
50	43·4	44·5	45·6	46·7	47·8	48·9	51·1	52·2	53·3	54·4	55·5
55	48·5	49·6	50·7	51·8	52·9	54·0	56·0	57·1	58·2	59·3	60·4
60	53·6	54·6	55·7	56·8	57·8	58·9	61·0	62·1	63·2	64·3	65·3
65	58·6	59·7	60·7	61·8	62·8	63·9	66·0	67·1	68·1	69·2	70·2
70	63·7	64·8	[illegible]	66·9	67·9	69·0	71·0	72·1	73·1	74·2	75·2
75	68·8	69·8	[illegible]	71·9	72·9	74·0	76·0	77·0	78·1	79·1	80·1
80	73·9	74·9	75·9	76·9	78·0	79·0	81·0	82·0	83·0	84·0	85·0
85	79·0	80·0	81·0	82·0	83·0	84·0	86·0	87·0	88·0	88·9	89·9
90	84·2	85·2	86·2	87·2	88·1	89.1	90·9	91·9	92·8	93·7	94·5

The preceding ten tables of TRALLES contain all that is requisite for the determination of the volume of alcohol in a liquid; they have been constructed on the principle of the tables of GILPIN. Since their construction, however, further extensive researches have been instituted by various eminent chemists, among whom was the famous GAY-LUSSAC, whose investigations had been made in 1824. The tables drawn up by that chemist are much more extensive, requiring scarcely any interpolation.

GAY-LUSSAC's instrument, called an *alcoomètre*, is like a glass hydrometer, the stem of which is divided into degrees like that of TRALLES, to indicate the per centage of alcohol by volume, but the temperature at which the gradation was made was 15° C. or 59° Fahr., instead of 60° Fahr., as the normal temperature of TRALLES' tables.

At this temperature, water is supposed to be at its maximum density or unity, although this actually happens when the temperature is reduced to 39·83° Fahr. The stem of the instrument is divided, from the point at which it stands in water, into one hundred divisions, so that each on the scale is equal to a per cent. of alcohol; the hundredth division indicates pure or absolute alcohol, while 0 or zero equals pure water.

The instrument, if immersed in an alcoholic liquor at 59°, marks the strength by the number of degrees below the surface; thus, if the alcoholometer stands at 57 in a liquid at 59°, such a solution contains 57 per cent. by volume of alcohol.

In consequence of the assumed density of water, taken by GAY-LUSSAC at 59°, the fundamental numbers for determining the relation, the per centage of alcohol and the specific gravities, are in a slight degree different from those of TRALLES, but the variation is so minute that in practice it may be overlooked.

In the annexed table the fundamental numbers of the centesimal content per volume, together with the specific gravities of the different alcoholic mixtures at 59°, are given:

Per cent. of alcohol by volume.	Specific gravity of the liquid at 59°.	Per cent. of alcohol by volume.	Specific gravity of the liquid at 59°.
100	0·7947	60	0·9141
95	0·8168	55	0·9248
90	0·8346	50	0·9348
85	0·8502	45	0·9440
80	0·8645	40	0·9523
75	0·8799	35	0·9595
70	0·8907	10	0·9656
65	0·9027	0	1·0000

The first table by GAY-LUSSAC is denominated *Table for the* REAL *strength of spirits*, and corresponds with Table VIII. of TRALLES. This table gives the true per centage by volume at 59° from the observed per centage of the alcoholometer at any other temperature. Two numbers are placed in the same horizontal column, and vertical to each other: those in the top are the observed centesimal quantities of the alcoholometer, while the large figures in the vertical column below them, give the real per centages at 59°, when tested at the temperature found in the left-hand vertical column. The numbers in small figures beneath the real per centages denote the bulk at 59° of a thousand measures of liquid; this number, multiplied by the real per centage under which it stands, gives the richness, or absolute quantity of alcohol at the temperature at which the experiment is performed. To read the table, suppose an alcoholic liquid of 50 strength indicated by the alcoholometer at a temperature of 68° Fahr., the observed per centage—50—is sought in the horizontal column at the top; in the vertical column beneath this and on a line with 68°, in the temperature column at the left hand, will be found the number 48·2, which is the quantity of *real* spirit at 59°. The number 996, in small figures below the indicated strength at 59°, is the bulk or volume which a thousand volumes would occupy at the standard temperature; and by multiplying this number by the proper strength, and dividing the product by a thousand, the strength or true volume of spirit in a thousand of the liquid is ascertained; thus—

$$996 \times 48{\cdot}2 = 48007{\cdot}2 \div 1000 = 48{\cdot}00, \text{ the per centage;}$$

hence, a hundred volumes of the liquor at 68°, contain 48 volumes of absolute alcohol at 59°.

M. MORAZEAU constructed a table somewhat more in detail than the foregoing, with one of GAY-LUSSAC's alcoholometers, which differs slightly from the preceding in the figures denoting the density, although they have reference to the same temperature.

When, however, the liquors to be tested stand at a higher degree than 59°, no provision is made to afford the true content of spirit, which must be sought, in this case, either by other tables, or by the tedious calculation exemplified on a former occasion.

Per cent. of alcohol by volume.	Specific gravity.	Per cent. of alcohol by volume.	Specific gravity.	Per cent. of alcohol by volume.	Specific gravity.
0	1·000	34	0·962	68	0·896
1	0·999	35	0·960	69	0·893
2	0·997	36	0·959	70	0·891
3	0·996	37	0·957	71	0·888
4	0·994	38	0·956	72	0·884
5	0·993	39	0·954	73	0·881
6	0·992	40	0·953	74	0·879
7	0·990	41	0·951	75	0·876
8	0·989	42	0·949	76	0·874
9	0·988	43	0·948	77	0·871
10	0·987	44	0·946	78	0·868
11	0·986	45	0·945	79	0·865
12	0·984	46	0·943	80	0·863
13	0·983	47	0·941	81	0·860
14	0·982	48	0·940	82	0·857
15	0·981	49	0·938	83	0·854
16	0·980	50	0·936	84	0·851
17	0·979	51	0·934	85	0·848
18	0·978	52	0·932	86	0·845
19	0·977	53	0·930	87	0·842
20	0·976	54	0·928	88	0·838
21	0·975	55	0·926	89	0·835
22	0·974	56	0·924	90	0·832
23	0·973	57	0·922	91	0·829
24	0·972	58	0·920	92	0·826
25	0·971	59	0·918	93	0·822
26	0·970	60	0·915	94	0·818
27	0·969	61	0·913	95	0·814
28	0·968	62	0·911	96	0·810
29	0·967	63	0·909	97	0·805
30	0·966	64	0·906	98	0·800
31	0·965	65	0·904	99	0·795
32	0·964	66	0·902	100	0·747
33	0·963	67	0·899		

TABLE I.

ALCOHOLOMETRIC TABLE BY GAY-LUSSAC,

To find the per cent., by volume, in a liquid at 59°—strength—from the observed per cent. at any other Temperature. The temperature by Centigrade is below that of Fahrenheit.

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	1 p.cent.	2 p.cent.	3 p.cent.	4 p.cent.	5 p.cent.	6 p.cent.	7 p.cent.	8 p.cent.	9 p.cent.	10 p.cent.
32·0° 0° C.	1·3 1000	2·4 1000	3·4 1000	4·4 1000	5·4 1000	6·5 1001	7·5 1001	8·6 1001	9·7 1001	10·9 1001
33·8 1 C.										
35·6 2 C.										
37·4 3 C.										
39·2 4 C.										
41·0 5 C.	1·4 1001	2·5 1001	3·5 1001	4·5 1001	5·5 1001	6·6 1001	7·7 1001	8·7 1001	9·8 1001	10·9 1001
42·8 6 C.										
44·6 7 C.										
46·4 8 C.										
48·2 9 C.										
50·0 10 C.	1·4 1000	2·4 1000	3·4 1001	4·5 1001	5·5 1001	6·5 1001	7·5 1001	8·5 1001	9·5 1001	10·6 1001
51·8 11 C.	1·3 1000	2·4 1000	3·4 1000	4·4 1001	5·4 1001	6·4 1001	7·4 1001	8·4 1001	9·4 1001	10·5 1001
53·6 12 C.	1·2 1000	2·3 1000	3·3 1000	4·3 1000	5·3 1000	6·3 1000	7·3 1000	8·3 1000	9·3 1000	10·4 1000
55·4 13 C.	1·2 1000	2·2 1000	3·2 1000	4·2 1000	5·2 1000	6·2 1000	7·2 1000	8·2 1000	9·2 1000	10·3 1000
57·2 14 C.	1·1 1000	2·1 1000	3·1 1000	4.1 1000	5·1 1000	6·1 1000	7·1 1000	8·1 1000	9·1 1000	10·2 1000
59·0 15 C.	1 1000	2 1000	3 1000	4 1000	5 1000	6 1000	7 1000	8 1000	9 1000	10 1000
60·8 16 C.	0·9 1000	1·9 1000	2·9 1000	3·9 1000	4·9 1000	5·9 1000	6·9 1000	7·9 1000	8·9 1000	9·9 1000
62·6 17 C.	0·8 1000	1·8 1000	2·8 1000	3·8 1000	4·8 1000	5·8 1000	6·8 1000	7·8 1000	8·8 1000	9·8 1000
64·4 18 C.	0·7 1000	1·7 1000	2·7 1000	3·7 1000	4·7 1000	5·7 1000	6·7 1000	7·7 1000	8·7 1000	9·7 1000
66·2 19 C.	0·6 999	1·6 999	2·6 999	3·6 999	4·5 999	5·5 999	6·5 999	7·5 999	8·5 999	9·5 999
68·0 20 C.	0·5 999	1·5 999	2·4 999	3·4 999	4·4 999	5·4 999	6·4 699	7·3 999	8·3 999	9·3 999
69·8 21 C.	0·4 999	1·4 999	2·3 999	3·3 999	4·3 999	5·2 999	6·2 999	7·1 999	8·1 999	9·1 999
71·6 22 C.	0·3 999	1·3 999	2·2 999	3·2 999	4·1 999	5·1 999	6·1 999	7 999	7·9 999	8·9 999
73·4 23 C.	0·1 999	1·1 999	2·1 999	3·1 999	4 999	4·9 599	5·9 999	6·8 998	7·8 998	8·7 998
75·2 24 C.		1 998	1·9 998	2·9 998	3·8 998	4·8 998	5·8 998	6·7 998	7·6 998	8·5 998
77·0 25 C.		0·8 998	1·7 998	2·7 998	3·6 998	4·6 998	5·5 998	6·5 998	7·4 998	8·3 998
78·8 26 C.		0·7 998	1·6 998	2·6 998	3·5 998	4·4 998	5·4 998	6·3 998	7·2 998	8·1 998
80·6 27 C.		0·5 998	1·5 998	2·4 998	3·3 998	4·3 998	5·2 998	6·1 998	7 998	7·9 998
82·4 28 C.		0·3 997	1·3 997	2·2 997	3·1 997	4·1 997	5 997	5·9 497	6·8 997	7·7 997
84·2 29 C.		0·1 997	1·1 997	2 997	2·9 997	3·9 997	4·8 997	5·7 997	6·6 997	7·5 697
86·0 30 C.		0·0 997	0·9 997	1·9 997	2·8 997	3·7 997	4·6 997	5·5 997	6·4 997	7·3 997

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	11 p.cent.	12 p.cent.	13 p.cent.	14 p.cent.	15 p.cent.	16 p.cent.	17 p.cent.	18 p.cent.	19 p.cent.	20 p.cent.
32·0° 0° C.	12·2 1001	13·4 1002	14·7 1002	16·1 1002	17·5 1002	18·9 1003	20·3 1003	21·6 1004	22·9 1004	24·2 1004
33·8 1 C.		13·4 1002	14·7 1002	16 1002	17·3 1002	18·7 1003	20 1003	21·3 1003	22·6 1004	23·9 1004
35·6 2 C.		13·4 1002	14·7 1002	16 1002	17·2 1002	18·5 1003	19·8 1003	21·1 1003	22·3 1004	23·6 1004
37·4 3 C.		13·3 1001	14·6 1002	15·9 1002	17·1 1002	18·3 1002	19·6 1003	20·8 1003	22 1003	23·3 1004
39·2 4 C.		13·3 1001	14·5 1002	15·8 1002	16·9 1002	18·1 1002	19·4 1002	20·6 1003	21·8 1003	23 1003
41·0 5 C.	12·1 1001	13·2 1001	14·4 1001	15·7 1002	16·8 1002	18 1002	19·2 1002	20·4 1003	21·5 1003	22·7 1003
42·8 6 C.		13·1 1001	14·3 1001	15·6 1002	16·7 1002	17·8 1002	19 1002	20·2 1003	21·3 1003	22·4 1003
44·6 7 C.		13 1001	14·2 1001	15·4 1001	16·6 1002	17·7 1002	18·8 1002	20 1002	21 1002	22·1 1002
46·4 8 C.		13 1001	14·1 1001	15·3 1001	16·4 1001	17·5 1001	18·6 1002	19·7 1002	20·7 1002	21·8 1002
48·2 9 C.		12·9 1001	14 1001	15·1 1001	16·2 1001	17·3 1001	18·4 1001	19·5 1001	20 5 1002	21·6 1002
50·0 10 C.	11·7 1001	12·7 1001	13·8 1001	14·9 1001	16 1001	17 1001	18·1 1001	19·2 1001	20·2 1001	21·3 1001
51·8 11 C.	11·6 1001	12·6 1001	13·6 1001	14·7 1001	15·8 1001	16·8 1001	17·9 1001	19 1001	20 1001	21 1001
53·6 12 C.	11·5 1000	12·5 1001	13·5 1001	14·6 1001	15·6 1001	16·6 1001	17·6 1001	18·7 1001	19·7 1001	20·7 1001
55·4 13 C.	11·4 1000	12·4 1000	13·4 1000	14·4 1000	15·4 1000	16·4 1000	17·4 1000	18·5 1000	19·5 1000	20·5 1000
57·2 14 C.	11·2 1000	12·2 1000	13·2 1000	14·2 1000	15·2 1000	16·2 1000	17·2 1000	18·2 1000	19·2 1000	20·2 1000
59·0 15 C.	11 1000	12 1000	13 1000	14 1000	15 1000	16 1000	17 1000	18 1000	19 1000	20 1000
60·8 16 C.	10·9 1000	11·9 1000	12·9 1000	13·9 1000	14·9 1000	15·9 1000	16·9 1000	17·8 1000	18·7 1000	19·7 1000
62·6 17 C.	10·8 1000	11·7 1000	12·7 1000	13·7 1000	14·7 1000	15·6 1000	16·6 1000	17·5 1000	18·4 999	19·4 999
64·4 18 C.	10·7 1000	11·6 1000	12·5 999	13·5 999	14·5 999	15·4 999	16·3 999	17·3 999	18·2 999	19·1 999
66·2 19 C.	10·5 999	11·4 999	12·4 999	13·3 999	14·3 999	15·2 999	16·1 999	17 999	17·9 999	18·8 999
68·0 20 C.	10·3 999	11·2 999	12·2 999	13·1 999	14 999	14·9 999	15·8 999	16·7 999	17·6 999	18·5 999
69·8 21 C.	10·1 999	11 999	11·9 999	12·8 999	13·7 999	14·6 999	15·5 998	16·4 998	17·3 998	18·2 998
71·6 22 C.	9·9 999	10·8 999	11·7 999	12·6 998	13·5 998	14·4 998	15·3 998	16·2 998	17 998	17·9 998
73·4 23 C.	9·7 998	10·6 998	11·5 998	12·4 998	13·3 998	14·1 998	15 998	15·9 998	16·7 998	17·6 998
75·2 24 C.	9·5 998	10·4 998	11·3 998	12·2 998	13·1 998	13·9 998	14·8 998	15·7 998	16·5 997	17·4 997
77·0 25 C.	9·3 998	10·2 998	11·1 998	12 998	12·8 998	13·6 998	14·5 997	15·4 997	16·2 997	17·1 997
78·8 26 C.	9 998	9·9 997	10·8 997	11·7 997	12·6 997	13·4 997	14·2 997	15·1 997	15·9 997	16·8 997
80·6 27 C.	8·8 997	9·7 997	10·6 997	11·5 997	12·3 997	13·1 997	14 997	14·8 997	15·6 997	16·5 997
82·4 28 C.	8·6 997	9·5 997	10·3 997	11·2 997	12 967	12·8 996	13·7 996	14·5 996	15·3 996	16·1 996
84·2 29 C.	8·4 997	9·2 997	10·1 997	11 997	11·8 996	12·6 996	13·4 996	11·2 996	15 996	15·8 996
86·0 30 C.	8·1 997	9 996	9·8 996	10·7 996	11·5 996	12·3 996	13·1 996	13·9 996	14·7 996	15·5 996

TABLE I.—Continued.

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	[illegible] p.cent.	22 p.cent.	23 p.cent.	24 p.cent.	25 p.cent.	26 p.cent.	27 p.cent.	28 p.cent.	29 p.cent.	30 p.cent.
32·0° 0° C.	25.6 1005	27 1005	28·4 1006	29·7 1006	30·9 1007	32·1 1007	33·2 1007	34·3 1008	35·3 1008	36·3 1008
33·8 1 C.	25·3 1005	26·7 1005	28 1005	29·2 1006	30·4 1006	31·6 1006	32·7 1007	33·8 1007	34·8 1007	35·8 1008
35·6 2 C.	24·9 1004	26·3 1005	27·5 1005	28·8 1005	30 1006	31·2 1006	32·3 1006	33·3 1006	34·4 1007	35·4 1007
37·4 3 C.	24·6 1004	25·9 1005	27·1 1005	28·4 1005	29·6 1005	30·8 1006	31·9 1006	32·9 1006	33·9 1007	34·9 1007
39·2 4 C.	24·3 1004	25·6 1004	26·8 1005	28 1005	29·2 1005	30·4 1005	31·4 1005	32·5 1005	33·5 1006	34·5 1006
41·0 5 C.	24 1003	25·2 1003	26·4 1004	27·6 1004	28·8 1004	30 1004	31 1005	32·1 1005	33·1 1005	34·1 1005
42·8 6 C.	23·6 1003	24·9 1003	26 1004	27·2 1004	28·4 1004	29·6 1004	30·6 1005	31·6 1005	32·6 1005	33·6 1005
44·6 7 C.	23·3 1002	24·6 1003	25·7 1003	26·9 1003	28 1003	29·2 1003	30·2 1004	31.2 1004	32·2 1004	33·2 1004
46·4 8 C.	23 1002	24·2 1002	25·3 1003	26·5 1003	27·6 1003	28·8 1003	29·8 1003	30·8 1003	31·8 1003	32·8 1003
48·2 9 C.	22·7 1002	23·9 1002	25 1002	26·1 1002	27·2 1002	28·4 1003	29·4 1003	30·4 1003	31·4 1003	32·4 1003
50·0 10 C.	22·4 1001	23·5 1002	24·6 1002	25·7 1002	26·8 1002	27·9 1002	29 1002	30 1002	31 1002	32 1002
51·8 11 C.	22·1 1001	23·2 1001	24·3 1001	25·4 1001	26·5 1002	27·6 1002	28·6 1002	29·6 1002	30·6 1002	31·6 1002
53·6 12 C.	21·8 1001	22·9 1001	24 1001	25·1 1001	26·1 1001	27·2 1001	28·2 1001	29·2 1001	30·2 1001	31·2 1001
55·4 13 C.	21·5 1001	22·6 1001	23·6 1001	24·7 1001	25·7 1001	26·8 1001	27·8 1001	28·8 1001	29·8 1001	30·8 1001
57·2 14 C.	21·2 1000	22·3 1000	23·3 1000	24·3 1000	25·3 1000	26·4 1000	27·4 1000	28·4 1000	29·4 1000	30·4 1000
59·0 15 C.	21 1001	22 1000	23 1000	24 1000	25 1000	26 1000	27 1000	28 1000	29 1000	30 1000
60·8 16 C.	20·7 1000	21·7 1000	22·7 1000	23·7 1000	24·7 1000	25·7 1000	26·6 1000	27·6 1000	28·6 1000	29·6 1000
62·6 17 C.	20·4 999	21·4 999	22·4 999	23·4 999	24·4 999	25·4 999	26·3 999	27·3 999	28·2 999	29·2 999
64·4 18 C.	20·1 999	21·1 999	22 999	23 999	24 999	25 999	25·9 999	26·9 999	27·8 999	28·8 999
66·2 19 C.	19·8 999	20·8 999	21·7 999	22·7 999	23·6 998	24·6 998	25·5 998	26·5 998	27·4 998	28·4 998
68·0 20 C.	19·5 999	20·5 998	21·4 998	22·4 998	23·3 998	24·3 998	25·2 998	26·1 998	27·1 998	28 998
69·8 21 C.	19·1 998	20·1 998	21.1 998	22·1 998	23 998	23·9 998	24·8 998	25·7 998	26·7 997	27·6 997
71·6 22 C.	18·8 998	19·8 998	20·7 998	21·7 997	22·6 997	23·6 997	24·4 997	25·3 997	26·3 997	27·2 997
73·4 23 C.	18·5 998	19·5 997	20·4 997	21 4 997	22·3 997	23 2 997	24·1 997	25 997	25·9 997	26·8 997
75·2 24 C.	18·3 997	19·2 997	20·1 997	21·1 997	21·9 997	22·8 997	23·7 997	24·6 996	25·5 996	26·4 996
77·0 25 C.	18 997	18·9 997	19·8 997	20·7 997	21·6 996	22·5 996	23·3 996	24·3 996	25·2 996	26·1 996
78·8 26 C.	17·7 997	18·6 996	19·5 996	20·4 996	21·3 996	22·2 996	23 996	23·9 996	24·8 995	25·7 995
80·6 27 C.	17·4 996	18·3 996	19·2 996	20·1 996	20·9 996	21·8 996	22·7 996	23·6 996	24·4 995	25·3 995
82·4 28 C.	17 996	18 996	18·9 996	19·7 995	20·6 995	21·5 995	22·3 995	23·2 995	24 995	24·9 994
84·2 29 C.	16·7 996	17·6 996	18·5 995	19·4 995	20·3 995	21·1 995	21·9 995	22·8 994	23·7 994	24·5 994
86·0 30 C.	16·4 995	17·3 995	18·2 995	19·1 995	19·9 995	20·8 994	21·6 994	22·5 994	23·3 994	24·2 994

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	31 p.cent.	32 p. cent.	33 p.cent.	34 p.cent.	35 p.cent.	36 p.cent.	37 p.cent.	38 p.cent.	39 p.cent.	40 p.cent.
32·0° 0° C.	37·3 1009	38·3 1009	39·2 1009	40·2 1009	41·1 1009	42·1 1010	43·1 1010	44 1010	45 1010	45·9 1011
33·8 1 C.	36·8 1008	37·8 1008	38·8 1008	39·8 1008	40·8 1009	41·8 1009	42·7 1009	43·7 1009	44·6 1010	45 5 1010
35·6 2 C.	36·4 1007	37·4 1007	38·4 1008	39·4 1008	40·4 1008	41·4 1008	42·3 1008	43·3 1009	44·2 1009	45·1 1009
37·4 3 C.	36 1007	37 1007	38 1007	39 1007	40 1007	41 1008	42 1008	42·9 1008	43·9 1008	44·8 1008
39·2 4 C.	35·5 1006	36·5 1006	37·5 1006	38·5 1007	39·5 1007	40·5 1007	41·5 1007	42·5 1007	43·5 1007	44·4 1008
41·0 5 C.	35·1 1005	36·1 1006	37·1 1006	38·1 1006	39·1 1006	40·1 1006	41·1 1007	42·1 1007	43·1 1007	44 1007
42·8 6 C.	34·7 1005	35·7 1005	36·7 1005	37·7 1005	38·7 1005	39·7 1006	40·7 1006	41 1006	42·6 1006	43·6 1006
44·6 7 C.	34·2 1004	35·2 1004	36·2 1004	37·2 1005	38·2 1005	39·2 1005	40·2 1005	41·2 1005	42·2 1005	43·2 1005
46·4 8 C.	33·8 1004	34·8 1004	35·8 1004	36·8 1004	37·8 1004	38·8 1004	39·8 1004	40·8 1004	41·8 1004	42·8 1005
48·2 9 C.	33·4 1003	34·4 1003	35·4 1003	36·4 1003	37·4 1004	38·4 1004	39·4 1004	40 4 1004	41·4 1004	42·4 1004
50·0 10 C.	33 1002	34 1002	35 1003	36 1003	37 1003	38 1003	39 1003	40 1003	41 1003	42 1003
51·8 11 C.	32·6 1002	33·6 1002	34·6 1002	35·6 1002	36·6 1002	37·6 1002	38·6 1002	39·6 1002	40·6 1003	41·6 1003
53·6 12 C.	32·2 1001	33·2 1001	34·2 1002	35·2 1002	36·2 1002	37·2 1002	38·2 1002	39·2 1002	40·2 1002	41·2 1002
55·4 13 C.	31·8 1001	32·8 1001	33·8 1001	34·8 1001	35·8 1001	36·8 1001	37·8 1001	38·8 1001	39·8 1001	40·8 1001
57·2 14 C.	31·4 1000	32·4 1000	33·4 1001	34·4 1001	35·4 1001	36·4 1001	37·4 1001	38·4 1001	39·4 1001	40·4 1001
59·0 15 C.	31 1000	32 1000	33 1000	34 1000	35 1000	36 1000	37 1000	38 1000	39 1000	40 1000
60·8 16 C.	30·6 1000	31·6 1000	32.5 999	33·5 999	34·5 999	35·5 999	36·5 999	37·5 999	38·5 999	39·5 999
62·6 17 C.	30·2 999	31·2 999	32·1 999	33·1 999	34·1 999	35·1 999	36·1 999	37 1 999	38·1 999	39·1 999
64·4 18 C.	29·8 999	30·8 999	31·7 998	32·7 998	33·7 998	34·7 998	35 7 998	36·7 998	37·7 998	38·7 998
66·2 19 C.	29·4 998	30·4 998	31·3 998	32·3 998	33·3 998	34·3 998	35·3 998	36·3 998	37·3 997	38·3 997
68·0 20 C.	29 998	30 998	30·9 997	31·9 997	32·9 997	33·9 997	34·9 997	35·9 997	36·9 997	37·9 997
69·8 21 C.	28·6 997	29·6 997	30·5 997	31·5 997	32·5 997	33·5 997	34·5 997	35·5 996	36·5 996	37·5 996
71·6 22 C.	28·2 997	29·2 997	30·1 996	31·1 996	32·1 996	33·1 996	34·1 996	35·1 996	36·1 996	37·1 996
73·4 23 C.	27·8 996	28·8 996	29·7 996	30·7 996	31·7 996	32·7 996	33·7 996	34·7 995	35·7 995	36·7 995
75·2 24 C.	27·4 996	28·4 996	29·3 995	30·3 995	31·3 995	32·3 995	33·3 995	34·3 995	35·3 995	36·3 994
77·0 25 C.	27 995	28 995	28·9 995	29·9 995	30·9 995	31·9 994	32·9 994	33·9 994	34·9 994	35·9 994
78·8 26 C.	26·6 995	27·6 995	28·5 995	29·5 994	30·5 994	31·5 994	32·5 994	33·5 994	34·5 993	35·5 993
80·6 27 C.	26·2 995	27·2 994	28·1 994	29·1 994	30·1 994	31·1 993	32·1 993	33·1 993	34·1 993	35·1 993
82·4 28 C	25·8 994	26·8 994	27·7 994	28·7 993	29·7 993	30·7 993	31·7 993	32·7 993	33·7 992	34·7 992
84·2 29 C.	25·4 994	26·4 993	27·3 993	28·3 993	29·3 993	30·3 992	31·3 992	32·3 992	33·3 992	34·3 992
86·0 30 C.	25·1 993	26 993	26·9 993	27·9 993	28·9 992	29·9 992	30·9 992	31·9 991	32·9 991	33·9 991

Table I.—Continued.

Temp Fahr.	Observed per centage of the Alcoholometer.									
	41 p.cent.	42 p.cent	43 p.cent.	44 p.cent	45 p.cent.	46 p.cent.	47 p.cent.	48 p.cent.	49 p.cent.	50 p.cent.
32·0° 0° C.	46·9 1011	47·9 1011	48·8 1011	49·8 1011	50·7 1011	51·7 1011	52·6 1012	53·5 1012	54·5 1012	55·4 1012
33·8 1 C.	46·5 1010	47·5 1010	48.4 1010	49·4 1010	50·3 1010	51·3 1011	52·2 1011	53·2 1011	54·2 1011	55·1 1011
35·6 2 C.	46·1 1009	47·1 1009	48·1 1009	49 1009	49·9 1010	50·9 1010	51·8 1010	52·8 1010	53·8 1010	54·7 1010
37·4 3 C.	45·8 1008	46·7 1009	47·7 1009	48·6 1009	49·6 1009	50·5 1009	51·5 1009	52·4 1009	53·4 1009	54·3 1009
39·2 4 C.	45·4 1008	46·4 1008	47·4 1008	48·3 1008	49·2 1008	50·2 1008	51·1 1008	52·1 1008	53 1008	54 1009
41·0 5 C.	45 1007	45·9 1007	46·9 1007	47·9 1007	48·8 1007	49·8 1007	50·7 1007	51·7 1008	52·7 1008	53·6 1008
42·8 6 C.	44·6 1006	45·5 1006	46·5 1006	47·5 1007	48·4 1007	49·4 1007	50·4 1007	51·4 1007	52·4 1007	53·3 1007
44·6 7 C.	44·2 1005	45·1 1006	46·1 1006	47·1 1006	48·1 1006	49·1 1006	50·1 1006	51 1006	52 1006	52·9 1006
46·4 8 C.	43·8 1005	44·8 1005	45·8 1005	46·8 1005	47·7 1005	48·7 1005	49·7 1005	50·6 1005	51·6 1005	52·6 1005
48·2 9 C.	43·4 1004	44·4 1004	45·4 1004	46·4 1004	47·3 1004	48·3 1004	49·3 1005	50·2 1005	51·2 1005	52·2 1005
50·0 10 C.	43 1003	44 1004	45 1004	46 1004	46·9 1004	47·9 1004	48·9 1004	49·9 1004	50·9 1004	51·8 1004
51·8 11 C.	42·6 1003	43·6 1003	44·6 1003	45·6 1003	46·6 1003	47·6 1003	48·6 1003	49·5 1003	50·5 1003	51·5 1003
53·6 12 C.	42·2 1002	43·2 1002	44·2 1002	45·2 1002	46·2 1002	47·2 1002	48·2 1002	49·2 1002	50·2 1002	51·1 1002
55·4 13 C.	41·8 1001	42·8 1001	43·8 1001	44·8 1002	45·8 1002	46·8 1002	47·8 1002	48·8 1002	49·8 1002	50·8 1002
57·2 14 C.	41·4 1001	42·4 1001	43·4 1001	44·4 1001	45·4 1001	46·4 1001	47·4 1001	48·4 1001	49·4 1001	50·4 1001
59·0 15 C.	41 1000	42 1000	43 1000	44 1000	45 1000	46 1000	47 1000	48 1000	49 1000	50 1000
60·8 16 C.	40·6 999	41·6 999	42·6 999	43·6 999	44·6 999	45·6 999	46·6 999	47·6 999	48·6 999	49·6 999
62·6 17 C.	40·2 999	41·2 999	42·2 999	43·2 998	44·2 998	45·2 998	46·2 998	47·2 998	48·3 998	49·3 998
64·4 18 C.	39·8 998	40·8 998	41·8 998	42·8 998	43·8 998	44·9 998	45·9 998	46·9 998	47·9 998	48·9 998
66·2 19 C.	39·4 997	40·4 997	41·4 997	42·5 997	43·5 997	44·5 997	45·5 997	46·5 997	47·5 997	48·5 997
68·0 20 C.	39 997	40 997	41 997	42·1 997	43·1 996	44·1 996	45·1 996	46·1 996	47·2 996	48·2 996
69·8 21 C.	38·6 996	39·6 996	40.6 996	41·7 996	42·7 996	43·7 996	44·8 996	45·8 996	46·8 995	47·8 995
71·6 22 C.	38·2 996	39·2 995	40·2 995	41·3 995	42·3 995	43·3 995	44·3 995	45·3 995	46·4 995	47·4 995
73·4 23 C.	37·8 995	38·8 995	39·8 995	40·9 994	41·9 994	42·9 994	43·9 994	44·9 994	46 994	47 994
75·2 24 C.	37·4 994	38·4 994	39·4 994	40·5 994	41·5 994	42·5 994	43·6 994	44·6 994	45·6 993	46·6 993
77·0 25 C.	37 994	38 994	39 993	40·1 993	41·1 993	42·2 993	43·2 993	44·2 993	45·2 993	46·3 993
78·8 26 C.	36·5 993	37·6 993	38·6 993	39·7 993	40·7 992	41·8 992	42·8 992	43·8 992	44·9 992	45·9 992
80·6 27 C.	36·1 992	37·2 992	38·2 992	39·3 992	40·3 992	41·4 992	42·4 992	43·4 991	44·5 991	45·5 991
82·4 28 C.	35·7 992	36·8 992	37·8 992	38·9 991	39·9 991	41 991	42 991	43 991	44·1 991	45·1 990
84·2 29 C.	35·3 991	36·3 991	37·4 991	38·5 991	39·5 991	40·6 990	41·6 990	42·6 990	43·7 990	44·7 990
86·0 30 C.	34·9 991	35·9 991	37 990	38·1 990	39·1 990	40·2 990	41·2 990	42·3 989	43·3 989	44·3 989

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	51 p.cent.	52 p.cent.	53 p.cent.	54 p.cent.	55 p.cent.	56 p.cent.	57 p.cent.	58 p.cent.	59 p.cent.	60 p.cent.
32·0° 0° C.	56·4 1012	57·3 1012	58·3 1012	59·2 1012	60·2 1012	61·2 1012	62·1 1012	63.1 1013	64·1 1013	65 1013
33·8 1 C.	56 1011	57 1011	57·9 1011	58·9 1011	59·9 1011	60·9 1011	61·8 1011	62·8 1012	63·8 1012	64·7 1012
35·6 2 C.	55·7 1010	56·6 1010	57·6 1010	58·5 1010	59·5 1010	60·5 1011	61·5 1011	62 4 1011	63·4 1011	64·4 1011
37·4 3 C.	55·3 1009	56·3 1009	57·2 1009	58·2 1010	59·2 1010	60·2 1010	61·1 1010	62·1 1010	63·1 1010	64·1 1010
39·2 4 C.	55 1009	56 1009	56·9 1009	57·9 1009	58·9 1009	59·8 1009	60·8 1009	61·7 1009	62·7 1009	63·7 1009
41·0 5 C.	54·6 1008	55·6 1008	56·6 1008	57·5 1008	58·5 1008	59·5 1008	60·4 1008	61·4 1008	62·4 1008	63·4 1008
42·8 6 C.	54·3 1007	55·2 1007	56·2 1007	57·1 1007	58·1 1007	59·1 1007	60·1 1007	61 1008	62 1008	63 1008
44·6 7 C.	53·9 1006	54·9 1006	55·9 1006	56·8 1006	57·8 1006	58·8 1006	59·8 1007	60·7 1007	61·7 1007	62·7 1007
46·4 8 C.	53·6 1005	54·6 1005	55·5 1006	56·5 1006	57·5 1006	58·5 1006	59·5 1006	60·4 1006	61·4 1006	62·4 1006
48·2 9 C.	53·2 1005	54·2 1005	55·1 1005	56·1 1005	57·1 1005	58·1 1005	59·1 1005	60 1005	61 1005	62 1005
50·0 10 C.	52·8 1004	53·8 1004	54·8 1004	55·8 1004	56·8 1004	57·8 1004	58·8 1004	59·7 1004	60·7 1004	61·7 1004
51·8 11 C.	52·5 1003	53·5 1003	54·4 1003	55·4 1003	56·4 1003	57·4 1003	58·4 1003	59·4 1003	60·4 1003	61·4 1003
53·6 12 C.	52·1 1002	53·1 1002	54·1 1002	55 1002	56 1002	57 1002	58 1002	59 1002	60 1002	61 1002
55·4 13 C.	51·8 1002	52·7 1002	53·7 1002	54·7 1002	55·7 1002	56·7 1002	57·7 1002	58·7 1002	59·7 1002	60·7 1002
57·2 14 C.	51·4 1001	52·3 1001	53·3 1001	54·3 1001	55·3 1001	56·3 1001	57·3 1001	58·3 1001	59·3 1001	60·3 1001
59·0 15 C.	51 1000	52 1000	53 1000	54 1000	55 1000	56 1000	57 1000	58 1000	59 1000	60 1000
60·8 16 C.	50·6 999	51·6 999	52.6 999	53·6 999	54·6 999	55·6 999	56·6 999	57·6 999	58·6 999	59·6 999
62·6 17 C.	50·3 998	51·3 998	52·3 998	53·3 998	54·3 998	55·3 998	56·3 998	57·3 998	58·3 998	59·3 998
64·4 18 C.	49·9 998	50·9 998	51·9 998	52·9 998	53·9 998	54·9 998	55·9 998	56·9 997	57·9 997	58·9 997
66·2 19 C.	49·5 997	50·6 997	51·6 997	52·6 997	53·6 997	54·6 997	55·6 997	56·6 997	57·6 997	58·6 997
68·0 20 C.	49·2 996	50·2 996	51·2 996	52·2 996	53·2 996	54·2 996	55·2 996	56·2 996	57·2 996	58·2 996
69·8 21 C.	48·8 995	49·8 995	50·8 995	51·8 995	52·9 995	53·9 995	54·9 995	55·9 995	56·9 995	57·9 995
71·6 22 C.	48·4 995	49·4 995	50·4 995	51·4 994	52·5 994	53·5 994	54·5 994	55·5 994	56·5 994	57·5 994
73·4 23 C.	48 994	49·1 994	50 1 994	51·1 994	52·1 994	53·1 994	54·1 993	55·1 993	56·1 993	57·1 993
75·2 24 C.	47·6 993	48·7 993	49·7 993	50·7 993	51·8 993	52·8 993	53·8 993	54·8 993	55·8 993	56·8 992
77·0 25 C.	47·3 993	48·3 993	49·3 993	50·3 992	51·4 992	52·4 992	53·4 992	54·4 992	55·5 992	56·5 992
78·8 26 C.	46·9 992	47·9 992	49 992	50 991	51 991	52 991	53 991	54 991	55·1 991	56·1 991
80·6 27 C.	46·5 991	47·6 991	48·6 991	49·6 991	50·7 990	51·7 990	52·7 990	53·7 990	54·8 990	55·8 990
82·4 28 C.	46·1 990	47·2 990	48·2 990	49·2 990	50·3 990	51·3 990	52·3 990	53·3 989	54·4 989	55·4 989
84·2 29 C.	45·7 990	46·8 989	47·8 989	48·9 989	49·9 989	51 989	52 989	53 989	54 989	55 988
86·0 30 C.	45·4 989	46·4 989	47·5 989	48·5 988	49·6 988	50·6 988	51·6 988	52·6 988	53·6 988	54·7 988

TABLE I.—Continued.

Temp Fahr.	Observed per centage of the Alcoholometer.									
	61 p.cent.	62 p.cent.	63 p.cent.	64 p.cent.	65 p.cent.	66 p.cent.	67 p.cent.	68 p.cent.	69 p.cent.	70 p.cent.
32·0° 0° C.	66 1013	67 1013	68 1013	68·9 1013	69·9 1013	70·8 1013	71·8 1013	72·7 1013	73·7 1014	74·7 1014
33·8 1 C.	65·7 1012	66·7 1012	67·7 1012	68·6 1012	69·6 1012	70·5 1012	71·5 1012	72·4 1012	73·4 1013	74·3 1013
35·6 2 C.	65·3 1011	66·3 1011	67·3 1011	68·3 1011	69·3 1011	70·2 1011	71·2 1011	72·1 1012	73·1 1012	74 1012
37·4 3 C.	65 1010	66 1010	67 1010	68 1010	68·9 1010	69·9 1011	70·8 1011	71·8 1011	72·8 1011	73·7 1011
39·2 4 C.	64·7 1009	65·7 1009	66·6 1009	67·6 1010	68·6 1010	69·5 1010	70·5 1010	71·5 1010	72·5 1010	73·4 1010
41·0 5 C.	64·3 1009	65·3 1009	66·3 1009	67·3 1009	68·3 1009	69·2 1009	70·2 1009	71·2 1009	72·2 1009	73·1 1009
42·8 6 C.	64 1008	65 1008	66 1008	67 1008	68 1008	68·9 1008	69·9 1008	70·9 1008	71·9 1008	72·8 1008
44·6 7 C.	63·7 1007	64·7 1007	65·7 1007	66·7 1007	67·6 1007	68·6 1007	69·6 1007	70·6 1007	71·5 1007	72·5 1007
46·4 8 C.	63·4 1006	64·4 1006	65·4 1006	66·4 1006	67·3 1006	68·3 1006	69·3 1006	70·2 1006	71·2 1006	72·2 1006
48·2 9 C.	63 1005	64 1005	65 1005	66 1005	67 1005	67·9 1005	68·9 1005	69·9 1005	70·9 1005	71·9 1005
50·0 10 C.	62·7 1004	63·7 1004	64·7 1004	65·7 1004	66·7 1004	67·6 1004	68·6 1004	69·6 1004	70·6 1004	71·6 1004
51·8 11 C.	62·4 1003	63·4 1003	64·4 1003	65·4 1003	66·4 1003	67·3 1003	68·3 1003	69·3 1004	70·3 1004	71·3 1004
53·6 12 C.	62 1002	63 1002	64 1002	65 1002	66 1002	67 1002	68 1003	69 1003	70 1003	71 1003
55·4 13 C.	61·7 1002	62·7 1002	63·7 1002	64·7 1002	65·7 1002	66·7 1002	67·7 1002	68·7 1002	69·6 1002	70·6 1002
57·2 14 C.	61·3 1001	62·3 1001	63·3 1001	64·3 1001	65·3 1001	66·3 1001	67·3 1001	68·3 1001	69·3 1001	70·3 1001
59·0 15 C.	61 1000	62 1000	63 1000	64 1000	65 1000	66 1000	67 1000	68 1000	69 1000	70 1000
60·8 16 C.	60·6 999	61·7 999	62·7 999	63·7 999	64·7 999	65·7 999	66·7 999	67·7 999	68·7 999	69·7 999
62·6 17 C.	60·3 998	61·3 998	62·3 998	63·3 998	64·3 998	65·3 998	66·3 998	67·3 998	68·3 998	69·3 998
64·4 18 C.	59·9 997	61 997	62 997	63 997	64 997	65 997	66 997	67 997	68 997	69 997
66·2 19 C.	59·6 997	60·6 997	61·6 997	62·7 997	63·7 997	64·7 997	65·7 997	66·7 997	67·7 993	68·7 996
68·0 20 C.	59·2 996	60·3 996	61·3 996	62·3 996	63·3 996	64·3 996	65·4 996	66·4 996	67·4 996	68·4 996
69·8 21 C.	58·9 995	59·9 995	61 995	62 995	63 995	64 995	65 995	66 995	67 995	68·1 995
71·6 22 C.	58·5 994	59·5 994	60·6 994	61·6 994	62·7 994	63·7 994	64·7 994	65·7 994	66·7 994	67·8 994
73·4 23 C.	58·1 993	59·2 993	60·2 993	61·3 993	62·3 993	63·3 993	64·3 993	65·4 993	66·4 993	67·4 993
75·2 24 C.	57·8 992	58·9 992	59·9 992	61 992	62 992	63 992	64 992	65 992	66 992	67·1 992
77·0 25 C.	57·5 992	58·5 992	59·5 992	60·6 991	61·6 991	62·6 991	63·7 991	64·7 991	65·7 991	66·7 991
78·8 26 C.	57·1 991	58·1 991	59·2 991	60·2 991	61·3 990	62·3 990	63·3 990	64·3 990	65·3 990	66·4 990
80·6 27 C.	56·8 990	57·8 990	58·9 990	59·9 990	60·9 990	61·9 990	63 989	64 989	65 989	66 989
82·4 28 C.	56·4 989	57·5 989	58·5 989	59·5 989	60·6 989	61·6 989	62·6 989	63·7 989	64·7 989	65·7 988
84·2 29 C.	56 988	57·1 988	58·1 983	59·2 988	60·2 988	61·2 988	62·3 988	63·3 988	64·3 988	65·4 988
86·0 30 C.	55·7 988	56·7 987	57·8 987	58·8 987	59·9 987	60·9 987	61·9 987	63 987	64 987	65 987

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	71 p.cent.	72 p.cent.	73 p.cent.	74 p.cent.	75 p.cent.	76 p.cent.	77 p.cent.	78 p.cent.	79 p.cent.	80 p.cent.
32·0° 0° C.	75·6 1014	76·6 1014	77·6 1014	78·6 1014	79·5 1014	80·5 1014	81·5 1014	82·4 1014	83·3 1014	84·3 1014
33·8 1 C.	75·3 1013	76·3 1013	77·3 1013	78·3 1013	79·2 1013	80·2 1013	81·2 1013	82·1 1013	83·1 1013	84 1013
35·6 2 C.	75 1012	76 1012	77 1012	78 1012	78·9 1012	79·9 1012	80·9 1012	81·9 1012	82·8 1012	83·7 1012
37·4 3 C.	74·7 1011	75·7 1011	76·7 1011	77·7 1011	78·6 1011	79·6 1011	80·6 1011	81·6 1011	82·5 1011	83·5 1011
39·2 4 C.	74·4 1010	75·3 1010	76·3 1010	77·3 1010	78·3 1010	79·3 1010	80·3 1010	81·3 1010	82·2 1010	83·2 1010
41·0 5 C.	74·1 1009	75 1009	76 1009	77 1009	78 1009	79 1009	80 1009	81 1009	81·9 1010	82·9 1010
42·8 6 C.	73·8 1008	74·7 1008	75·7 1008	76·7 1008	77·7 1008	78·7 1008	79·7 1008	80·7 1008	81·6 1008	82·6 1009
44·6 7 C.	73·5 1007	74·4 1007	75·4 1007	76·4 1007	77·4 1007	78·4 1007	79·4 1007	80·4 1007	81·4 1007	82·3 1008
46·4 8 C.	73·2 1006	74·1 1006	75·1 1006	76·1 1006	77·1 1006	78·1 1006	79·1 1007	80·1 1007	81·1 1007	82 1007
48·2 9 C.	72·9 1005	73·8 1005	74·8 1005	75·8 1005	76·8 1005	77·8 1005	78·8 1006	79·8 1006	80·8 1006	81·7 1006
50·0 10 C.	72·6 1004	73·5 1004	74·5 1005	75·5 1005	76·5 1005	77·5 1005	78·5 1005	79·5 1005	80·5 1005	81·5 1005
51·8 11 C.	72·3 1004	73·2 1004	74·2 1004	75·2 1004	76·2 1004	77·2 1004	78·2 1004	79·2 1004	80·2 1004	81·2 1004
53·6 12 C.	72 1003	72·9 1003	73·9 1003	74·9 1003	75·9 1003	76·9 1003	77·9 1003	78·9 1003	79·9 1003	80·9 1003
55·4 13 C.	71·6 1002	72·6 1002	73·6 1002	74·6 1002	75·6 1002	76·6 1002	77·6 1002	78·6 1002	79·6 1002	80·6 1002
57·2 14 C.	71·3 1001	72·3 1001	73·3 1001	74·3 1001	75·3 1001	76·3 1001	77·3 1001	78·3 1001	79·3 1001	80·3 1001
59·0 15 C.	71 1000	72 1000	73 1000	74 1000	75 1000	76 1000	77 1000	78 1000	79 1000	80 1000
60·8 16 C.	70·7 999	71·7 999	72.7 999	73·7 999	74·7 999	75·7 999	76·7 999	77·7 999	78·7 999	79·7 999
62·6 17 C.	70·3 998	71·3 998	72·3 998	73·3 998	74·3 998	75·4 998	76·4 998	77·4 998	78·4 998	79·4 998
64·4 18 C.	70 997	71 997	72 997	73 997	74 997	75·1 997	76·1 997	77·1 997	78·1 997	79·1 997
66·2 19 C.	69·7 996	70·7 996	71·7 996	72·7 996	73·7 996	74·7 996	75·8 996	76·8 996	77·8 996	78·8 996
68·0 20 C.	69·4 996	70·4 996	71·4 995	72·4 995	73·4 995	74·4 995	75·5 995	76·5 995	77·5 995	78·5 995
69·8 21 C.	69·1 995	70·1 995	71·1 995	72·1 994	73·1 994	74·1 994	75·2 994	76·2 994	77·2 994	78·2 994
71·6 22 C.	68·8 994	69·8 994	70·8 994	71·8 994	72·8 993	73·8 993	74·8 993	75·9 993	76·9 993	77·9 993
73·4 23 C.	68·4 993	69·4 993	70·5 993	71·5 993	72·5 992	73·5 992	74·5 992	75·5 992	76·6 992	77·6 992
75·2 24 C.	68·1 992	69·1 992	70·1 992	71·2 992	72·2 992	73·2 992	74·2 992	75·2 991	76·3 991	77·3 991
77·0 25 C.	67·8 991	68·8 991	69·8 991	70·8 991	71·8 991	72·8 991	73·9 991	74·9 991	76 991	77 991
78·8 26 C.	67·4 990	68·4 990	69·5 990	70·5 990	71.5 990	72·5 990	73·6 990	74·6 990	75·6 990	76·7 990
80·6 27 C.	67·1 989	68·1 989	69·2 989	70·2 989	71·2 989	72·2 989	73·3 989	74·3 989	75·3 989	76·3 989
82·4 28 C.	66·8 988	67·8 988	68·8 988	69·9 988	70·9 988	71·9 988	73 988	74 988	75 988	76 988
84·2 29 C.	66·4 988	67·4 987	68·5 987	69·5 987	70·6 987	71·6 987	72·6 987	73·7 987	74·7 987	75·7 987
86·0 30 C.	66·1 987	67·1 987	68·2 986	69·2 986	70·3 986	71·3 986	72·3 986	73·3 986	74·4 986	75·4 986

TABLE I.—Concluded.

Temp Fahr.	Observed per centage of the Alcoholometer.									
	81 p.cent.	82 p.cent.	83 p.cent.	84 p.cent.	85 p.cent.	86 p.cent.	87 p.cent.	88 p.cent.	89 p.cent.	90 p.cent.
32·0° 0° C.	85·2 1014	86·2 1014	87·1 1014	88 1014	88·9 1014	89·9 1015	90·8 1015	91·7 1015	92·6 1015	93·6 1015
33·8 1 C.	85 1013	85·9 1013	86·8 1013	87·8 1013	88·7 1013	89·6 1014	90·5 1014	91·5 1014	92·4 1014	93·3 1014
35·6 2 C.	84·7 1012	85·6 1012	86·6 1012	87·5 1012	88·5 1012	89·4 1013	90·3 1013	91·2 1013	92·2 1013	93·1 1013
37·4 3 C.	84·4 1011	85·4 1011	86·3 1011	87·3 1011	88·2 1011	89·2 1012	90·1 1012	91 1012	91·9 1012	92·9 1012
39·2 4 C.	84·2 1011	85·1 1011	86·1 1011	87 1011	87·9 1011	88·9 1011	89·8 1011	90·8 1011	91·7 1011	92·7 1011
41·0 5 C.	83·9 1010	84·8 1010	85·8 1010	86·7 1010	87·7 1010	88·6 1010	89·6 1010	90·5 1010	91·5 1010	92·4 1010
42·8 6 C.	83·6 1009	84·5 1009	85·5 1009	86·5 1009	87·4 1009	88·4 1009	89·3 1009	90·2 1009	91·2 1009	92·2 1009
44·6 7 C.	83·3 1008	84·2 1008	85·2 1008	86·2 1008	87·2 1008	88·1 1008	89·1 1008	90 1008	91 1008	91·9 1008
46·4 8 C.	83 1007	84 1007	85 1007	85·9 1007	86·9 1007	87·9 1007	88·8 1007	89·8 1007	90·7 1007	91·7 1007
48·2 9 C.	82·7 1006	83·7 1006	84·7 1006	85·7 1006	86·6 1006	87·6 1006	88·6 1006	89·5 1006	90·5 1006	91·5 1006
50·0 10 C.	82·4 1005	83·4 1005	84·4 1005	85·4 1005	86·4 1005	87·4 1005	88·3 1005	89·3 1005	90·2 1005	91·2 1005
51·8 11 C.	82·2 1004	83·1 1004	84·1 1004	85·1 1004	86·1 1004	87·1 1004	88 1004	89 1004	90 1004	91 1004
53·6 12 C.	81·9 1003	82·9 1003	83·9 1003	84·8 1003	85·8 1003	86·8 1003	87·8 1003	88·7 1003	89·7 1003	90·7 1003
55·4 13 C.	81·6 1002	82·6 1002	83·6 1002	84·6 1002	85·5 1002	86·5 1002	87·5 1002	88·5 1002	89·5 1002	90·5 1002
57·2 14 C.	81·3 1001	82·3 1001	83·3 1001	84·3 1001	85·3 1001	86·3 1001	87·3 1001	88·2 1001	89·2 1001	90·2 1001
59·0 15 C.	81 1000	82 1000	83 1000	84 1000	85 1000	86 1000	87 1000	88 1000	89 1000	90 1000
60·8 16 C.	80·7 999	81·7 999	82·7 999	83·7 999	84·7 999	85·7 999	86·7 999	87·7 999	88·7 999	89·7 999
62·6 17 C.	80·4 998	81·4 998	82·4 998	83·4 998	84·4 998	85·4 998	86·4 998	87·4 998	88·4 998	89·5 998
64·4 18 C.	80·1 997	81·1 997	82·1 997	83·1 997	84·1 997	85·2 997	86·2 997	87·2 997	88·2 997	89·2 997
66·2 19 C.	79·8 996	80·8 996	81·9 996	82·9 996	83·9 996	84·9 996	85·9 996	86·9 996	87·9 996	88·9 996
68·0 20 C.	79·5 995	80·5 995	81·6 995	82·6 995	83·6 995	84·6 995	85·6 995	86·6 995	87·7 995	88·7 995
69·8 21 C.	79·2 994	80·2 994	81·3 994	82·3 994	83·3 994	84·3 994	85·3 994	86·4 994	87·4 994	88·4 994
71·6 22 C.	78·9 993	79·9 993	81 993	82 993	83 993	84 993	85 993	86·1 993	87·1 993	88·2 993
73·4 23 C.	78·6 992	79·6 992	80·7 992	81·7 992	82·7 992	83·8 992	84·8 992	85·8 992	86·8 992	87·9 992
75·2 24 C.	78·3 991	79·3 991	80·4 991	81·4 991	82·4 991	83·5 991	84·5 991	85·5 991	86·5 991	87·6 991
77·0 25 C.	78 991	79 991	80·1 990	81·1 990	82·1 990	83·2 990	84·2 990	85·2 990	86·3 990	87·4 990
78·8 26 C.	77·7 990	78·7 989	79·8 989	80·8 989	81·8 989	82·9 989	83·9 989	84·9 989	86 989	87·1 989
80·6 27 C.	77·4 989	78·4 988	79·5 988	80·5 988	81·5 988	82·6 988	83·6 988	84·7 988	85·7 988	86 8 988
82·4 28 C.	77·1 988	78·1 988	79·2 987	80·2 987	81·2 987	82·3 987	83·3 987	84·4 987	85·4 987	86·5 987
84·2 29 C.	76·7 987	77·8 987	78·9 987	79·9 986	80·9 986	82 986	83 986	84·1 986	85·1 986	86·2 986
86·0 30 C.	76·4 986	77·7 986	78·6 986	79·6 986	80·6 985	81·7 985	82·7 985	83·8 985	84·9 985	86 985

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	91 p.cent.	92 p.cent.	93 p.cent.	94 p.cent.	95 p.cent.	96 p.cent.	97 p.cent.	98 p.cent.	99 p.cent.	100 p.cent.
32·0° 0° C.	94·5 1015	95·3 1015	96·2 1015	97·1 1015	98 1015	98·8 1015	99·7 1016			
33·8 1 C.	94·3 1014	95·1 1014	96 1014	96·9 1014	97·8 1014	98·6 1014	99·5 1014			
35·6 2 C.	94 1013	94·9 1013	95·8 1013	96·7 1013	97·6 1013	98·5 1013	99·3 1014			
37·4 3 C.	93·8 1012	94·7 1012	95·6 1012	96·5 1012	97·4 1012	98·3 1012	99·2 1012	1012		
39·2 4 C.	93·6 1011	94·5 1011	95·4 1011	96·3 1011	97·2 1011	98·1 1011	99 1011	99·9 1011		
41·0 5 C.	93·4 1010	94·3 1010	95·2 1010	96·1 1010	97 1010	97·9 1010	98·8 1010	99·7 1010		
42·8 6 C.	93·1 1009	94·1 1009	95 1009	95·9 1009	96·8 1009	97·8 1009	98·7 1009	99·6 1009		
44·6 7 C.	92·9 1008	93·9 1008	94·8 1008	95·7 1008	96·6 1008	97·6 1008	98·5 1008	99·4 1008		
46·4 8 C.	92·7 1007	93·6 1007	94·6 1007	95·5 1007	96·4 1007	97·4 1007	98·3 1007	99·2 1007	1007	
48·2 9 C.	92·5 1006	93·4 1006	94·4 1006	95·3 1006	96·2 1006	97·2 1006	98·1 1006	99·1 1006	100 1006	
50·0 10 C.	92·2 1005	93·2 1005	94·2 1005	95·1 1005	96 1005	97 1005	98 1005	98·9 1005	99·9 1005	
51·8 11 C.	92 1004	92·9 1004	93·9 1004	94·9 1004	95·8 1004	96·8 1004	97·8 1004	98·7 1004	99·7 1004	
53·6 12 C.	91·7 1003	92·7 1003	93·7 1003	94·7 1003	95·6 1003	96·6 1003	97·6 1003	98·5 1003	99·5 1003	
55·4 13 C.	91·5 1002	92·5 1002	93·5 1002	94·4 1002	95·4 1002	96·4 1002	97·4 1002	98·4 1002	99·3 1002	
57·2 14 C.	91·2 1001	92·2 1001	93·2 1001	94·2 1001	95·2 1001	96·2 1001	97·2 1001	98·2 1001	99·2 1001	
59·0 15 C.	91 1000	92 1000	93 1000	94 1000	95 1000	96 1000	97 1000	98 1000	99 1000	100 1000
60·8 16 C.	90·8 999	91·8 999	92.8 999	93·8 999	94·8 999	95·8 999	96·8 999	97·8 999	98·8 999	99·8 999
62·6 17 C.	90·5 998	91·5 998	92·6 998	93·6 998	94·6 998	95·6 998	96·6 998	97·6 998	98·7 998	99·7 998
64·4 18 C.	90·2 997	91·3 997	92·3 997	93·3 997	94·3 997	95·4 997	96·4 997	97·4 997	98·5 997	99·5 997
66·2 19 C.	90 996	91·1 996	92·1 996	93·1 996	94·1 996	95·2 996	96·2 996	97·3 996	98·3 996	99·3 996
68·0 20 C.	89·7 995	90·8 995	91·8 995	92·9 995	93·9 995	95 995	96 995	97·1 995	98·1 995	99·1 995
69·8 21 C.	89·5 994	90·5 994	91·6 994	92·6 994	93·7 994	94·7 994	95·8 994	96·9 994	97·9 994	99 994
71·6 22 C.	89·2 993	90·2 993	91·3 993	92·4 993	93·4 993	94·5 993	95·6 993	96·7 993	97·7 993	98·8 993
73·4 23 C.	89 992	90 992	91·1 992	92·1 992	93·2 992	94·3 992	95·4 992	96·5 992	97·5 992	98·6 992
75·2 24 C.	88·7 991	89·7 991	90·8 991	91·9 991	93 991	94·1 991	95·2 991	96·2 991	97·3 991	98·4 991
77·0 25 C.	88·4 990	89·5 990	90·6 990	91·6 990	92·7 990	93·8 990	94·9 990	96 990	97·1 990	98·2 990
78·8 26 C.	88·2 989	89·2 989	90·3 989	91·4 989	92.5 989	93·6 989	94·7 989	95·8 989	96·9 989	98·1 989
80·6 27 C.	87·9 988	89 988	90·1 988	91·1 988	92·2 988	93·4 988	94·5 988	95·6 987	96·7 987	97·9 987
82·4 28 C.	87·6 987	88·7 987	89·8 987	90·9 987	92 987	93·1 987	94·3 987	95·4 986	96·5 986	97·7 986
84·2 29 C.	87·3 986	88·4 986	89·5 986	90·6 986	91·7 986	92·9 986	94·1 986	95·2 986	96·3 985	97·5 985
86·0 30 C.	87·1 985	88·2 985	89·3 985	90·4 985	91·5 985	92·7 985	93·8 985	95 985	96·1 984	97·3 984

The second of GAY-LUSSAC's tables corresponds to Table VII. of TRALLES, and gives directly, but less accurately, that which by the former table is only obtained by a calculation, namely, the per centage by volume of the liquid at any temperature at which it is tested, from the observed per cent. Thus, if, as in the former example, the alcoholometer indicated 59 per cent. in the liquid at 77°, the observed per cent., 59, is sought for in the upper horizontal column, and in the vertical column below it that number is then taken which is in the same horizontal column with the observed temperature, 77°, in the left-hand column, which in this case is 55, or the liquid at the observed temperature of 77° contains 55 volumes of anhydrous alcohol.

TABLE II.

ALCOHOLOMETRIC TABLE OF GAY-LUSSAC,

To find directly the per centage of absolute alcohol of a liquid at any temperature—its richness—from the observed per centage at the same temperature.

Temp.		Observed per centage of the Alcoholometer.																			
Fahr.	Cent.	1 p.cent.	2 p.cent.	3 p.cent.	4 p.cent.	5 p.cent.	6 p.cent.	7 p.cent.	8 p.cent.	9 p.cent.	10 p.cent.	11 p.cent.	12 p.cent.	13 p.cent.	14 p.cent.	15 p.cent.	16 p.cent.	17 p.cent.	18 p.cent.	19 p.cent.	20 p.cent.
32·0	0	1·3	2.4	3·4	4·4	5·4	6·5	7 5	8·6	9·7	10·9	12·2	13·4	14·7	16·1	17·5	19	20·4	21·7	23	24·3
33·8	1											—	13·4	14·7	16	17·3	18·7	20·1	21·4	22·7	24
35·6	2											—	13·4	14·7	16	17·2	18·6	19·9	21·2	22·4	23·7
37·4	3											—	13·3	14·6	15·9	17·1	18·3	19·7	20·9	22·1	23·4
39·2	4											—	13·3	14·5	15·8	16·9	18·1	19·4	20·7	21·9	23·1
41·0	5	1·4	2·5	3·5	4·5	5·5	6·6	7·7	8·7	9·8	10·9	12·1	13·2	14·4	15·7	16·8	18	19·2	20·5	21·6	22·8
42·8	6											—	13·1	14·3	15·6	16·7	17·8	19	20·3	21·4	22·5
44·6	7											—	13	14·2	15·4	16·6	17·7	18·8	20	21	22·1
46·4	8											—	13	14·1	15·3	16·4	17·5	18·6	19·7	20·7	21·8
48·2	9											—	12·9	14	15·1	16·2	17·3	18·4	19·5	20·5	21·6
50·0	10	1·4	2·4	3·4	4·5	5·5	6·5	7·5	8·5	9·5	10·6	11·7	12·7	13·8	14·9	16	17	18·1	19·2	20·2	21·3
51·8	11	1·3	2·4	3·4	4·4	5·4	6·4	7·4	8·4	9·4	10·5	11·6	12·6	13·6	14·7	15·8	16·8	17·9	19	20	21
53·6	12	1·2	2·3	3·3	4·3	5·3	6·3	7·3	8·3	9·3	10·4	11·5	12·5	13·5	14·6	15·6	16·6	17·6	18·7	19·7	20·7
55·4	13	1·2	2·2	3·2	4·2	5·2	6·2	7·2	8·2	9·2	10·3	11·4	12·4	13·4	14·4	15·4	16·4	17·4	18·5	19·5	20·5
57·2	14	1·1	2·1	3·1	4·1	5·1	6·1	7·1	8·1	9·1	10·2	11·2	12·2	13·2	14·2	15·2	16·2	17·2	18·2	19·2	20·2
59·0	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
60·8	16	0·9	1·9	2·9	3·9	4·9	5·9	6 9	7·9	8·9	9·9	10·9	11·9	12·9	13·9	14·9	15·9	16·9	17·8	18·7	19·7
62·6	17	0·8	1·8	2·8	3·8	4·8	5·8	6·8	7·8	8·8	9·8	10·8	11·7	12·7	13·7	14·7	15·6	16·6	17·5	18·4	19·4
64·4	18	0·7	1·7	2·7	3·7	4·7	5·7	6·7	7·7	8·7	9·7	10·7	11·6	12·5	13·5	14·5	15·4	16·3	17·3	18·2	19·1
66·2	19	0·6	1·6	2·6	3·6	4·5	5·5	6·5	7·5	8·5	9·5	10·5	11·4	12·4	13·3	14·3	15·2	16·1	17	17·9	18·8
68·0	20	0·5	1·5	2·4	3·4	4·4	5·4	6·4	7·3	8·3	9·3	10·3	11·2	12·2	13·1	14	14·9	15·8	16·7	17·6	18·5
69·8	21	0·4	1·4	2·3	3·3	4·3	5·2	6·2	7·1	8·1	9·1	10·1	11	11·9	12·8	13·7	14·6	15·5	16·4	17·3	18·2
71·6	22	0·3	1·3	2·2	3·2	4·1	5·1	6·1	7	7·9	8·9	9·9	10·8	11·7	12·6	13·5	14·4	15·3	16·2	17	17·9
73·4	23	0·1	1·1	2·1	3·1	4	4·9	5·9	6·8	7·8	8·7	9·7	10·6	11·5	12·4	13·3	14·1	15	15·9	16·7	17·6
75·2	24	0·0	1	1·9	2·9	3·8	4·8	5·8	6·7	7·6	8·5	9·5	10·4	11·3	12·2	13·1	13·9	14·8	15·7	16·5	17·4
77·0	25	—	0·8	1·7	2·7	3·6	4·6	5·5	6·5	7·4	8·3	9·3	10·2	11·1	12	12·8	13·6	14·5	15·4	16·2	17·1
78·8	26	—	0·7	1·6	2·6	3·5	4·4	5·4	6·3	7 2	8·1	9	9·9	10·8	11·7	12·6	13·4	14·2	15·1	15·9	16·7
80·6	27	—	0·5	1·5	2·4	3·3	4·3	5·2	6·1	7	7·9	8·8	9·7	10·6	11·5	12·3	13·1	13·9	14·8	15·6	16·4
82·4	28	—	0·3	1·3	2·2	3·1	4·1	5	5·9	6·8	7·7	8·6	9·5	10·3	11·2	12	12·8	13·6	14·4	15·2	16
84·2	29	—	0·1	1·1	2	2·9	3·9	4·8	5·7	6·6	7·5	8·4	9·2	10·1	11	11·7	12·5	13·3	14·1	14·9	15 7
86·0	30	—	0·0	0·9	1·9	2·8	3·7	4·6	5·5	6·4	7·3	8·1	9	9·8	10·7	11·5	12·3	13	13·8	14·6	15·4

Temp																					
Fahr.	Cent.	21 p.cent.	22 p.cent.	23 p.cent.	24 p.cent.	25 p.cent.	26 p.cent.	27 p.cent.	28 p.cent.	29 p.cent.	30 p.cent.	31 p.cent.	32 p.cent.	33 p.cent.	34 p.cent.	35 p.cent.	36 p.cent.	37 p.cent.	38 p.cent.	39 p.cent.	40 p.cent.
32·0	0	25·7	27·1	28·5	29·9	31·1	32·3	33·4	34·5	35·6	36·6	37·6	38·5	39·6	40·6	41·5	42·5	43·5	44·4	45·4	46·4
33·8	1	25·4	26·8	28·1	29·4	30·6	31·8	32·9	34	35·1	36·1	37·1	38·1	39·1	40·1	41·2	42·2	43·1	44·1	45	46
35·6	2	25	26·4	27·6	28·9	30·2	31·4	32·5	33·5	34·6	35·6	36·7	37·7	38·7	39·7	40·7	41·7	42·7	43·7	44·6	45·5
37·4	3	24·7	26	27·3	28·6	29·8	31	32·1	33·1	34·1	35·2	36·2	37·3	38·3	39·3	40·3	41·3	42·3	43·2	44·2	45·2
39·2	4	24·4	25·7	26·9	28·1	29·3	30·6	31·6	32·7	33·7	34·7	35·7	36·7	37·7	38·8	39·8	40·8	41·8	42·8	43·8	44·8
41·0	5	24·1	25·3	26·5	27·7	28·9	30·1	31·2	32·3	33·3	34·3	35·3	36·3	37·3	38·3	39·3	40·3	41·4	42·4	43·4	44·4
42·8	6	23·7	25	26·1	27·3	28·5	29·7	30·8	31·8	32·8	33·8	34·9	35·9	36·9	37·9	38·9	39·9	40·9	41·9	42·9	43·9
44·6	7	23·4	24·7	25·8	27	28·1	29·3	30·3	31·3	32·3	33·3	34·3	35·4	36·4	37·4	38·4	39·4	40·4	41·4	42·4	43·4
46·4	8	23	24·2	25·4	26·6	27·7	28·9	29·9	30·9	31·9	32·9	33·9	34·9	35·9	36·9	38	39	40	41	42	43
48·2	9	22·7	23·9	25	26·2	27·3	28·5	29·5	30·5	31·5	32·5	33·5	34·5	35·5	36·5	37·5	38·6	39·6	40·6	41·6	42·6
50·0	10	22·4	23·5	24·6	25·8	26·9	28	29·1	30·1	31·1	32·1	33·1	34·1	35·1	36·1	37·1	38·1	39·1	40·1	41·1	42·1
51·8	11	22·1	23·2	24·3	25·4	26·5	27·7	28·7	29·7	30·7	31·7	32·7	33·7	34·7	35·7	36·7	37·7	38·7	39·7	40·7	41·7
53·6	12	21·8	22·9	24	25·1	26·1	27·2	28·2	29·2	30·2	31·2	32·2	33·2	34·3	35·3	36·3	37·3	38·3	39·3	40·3	41·3
55·4	13	21 5	22·6	23·7	24·7	25·7	26·8	27·8	28·8	29·8	30·8	31·8	32·8	33·8	34·8	35·8	36·8	37·8	38·8	39·8	40·9
57·2	14	21·2	22·3	23·3	24·3	25·3	26·4	27·4	28·4	29·4	30·4	31·4	32·4	33·4	34·4	35·4	36·4	37·4	38·4	39·4	40·4
59·0	15	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
60·8	16	20·7	21·7	22·7	23·7	24·7	25·7	26·6	27·6	28·6	29·6	30·6	31·6	32·5	33·5	34·5	35·5	36·5	37·5	38·5	39·5
62·6	17	20·4	21·4	22·4	23·4	24·4	25·4	26·3	27·3	28·2	29·2	30·2	31·2	32·1	33·1	34·1	35·1	36·1	37·1	38·1	39·1
64·4	18	20·1	21·1	22	23	24	25	25·9	26·9	27·8	28·8	29·8	30·8	31·7	32·6	33.6	34·6	35·6	36·6	37·6	38·6
66·2	19	19·8	20·8	21·7	22·7	23·6	24·6	25·5	26·4	27·3	28·3	29·3	30·3	31·2	32·2	33·2	34·2	35·2	36·2	37·2	38·2
68·0	20	19·5	20·5	21·4	22·4	23·3	24·3	25·2	26·1	27	27·9	28·9	29·9	30·8	31·8	32·8	33·8	34·8	35·8	36·8	37·8
69·8	21	19·1	20·1	21·1	22·1	22·9	23·9	24·8	25·6	26·6	27·5	28·5	29·5	30·4	31·4	32·4	33·4	34·4	35·4	36·4	37·4
71·6	22	18·8	19·8	20·7	21·6	22·5	23·5	24·3	25·2	26·2	27·1	28·1	29·1	30	31	32	33	34	35	36	36·9
73·4	23	18·5	19·4	20·3	21·3	22·2	23·1	24	24·9	25·8	26·7	27·7	28·7	29·6	30·6	31·6	32·6	33·5	34·5	35·5	36·5
75·2	24	18·2	19·1	20	21	21·8	22·7	23·6	24·5	25·4	26·3	27·3	28·3	29·2	30·2	31·1	32·1	33·1	34·1	35·1	36·1

TABLE II.—Continued.

Temp.		Observed per centage of the Alcoholometer.																			
Fahr.	Cent.	21 p.cent.	22 p.cent.	23 p.cent.	24 p.cent.	25 p.cent.	26 p.cent.	27 p.cent.	28 p.cent.	29 p.cent.	30 p.cent.	31 p.cent.	32 p.cent.	33 p.cent.	34 p.cent.	35 p.cent.	36 p.cent.	37 p.cent.	38 p.cent.	39 p.cent.	40 p.cent.
77·0	25	17·9	18·8	19·7	20·6	21·5	22·4	23·2	24·2	25·1	26	26·9	27·9	28·8	29·7	30·7	31·7	32·7	33·7	34·7	35·7
78·8	26	17·6	18·5	19·4	20·3	21·2	22·1	22·9	23·8	24·7	25·6	26·5	27·5	28·4	29·3	30·3	31·3	32·3	33·3	34·3	35·3
80·6	27	17·3	18·2	19·1	20	20·8	21·7	22·6	23·5	24·3	25·2	26·1	27·1	27·9	28·9	29·9	30·9	31·9	32·9	33·9	34·8
82·4	28	16·9	17·9	18·8	19·6	20·5	21·4	22·2	23·1	23·9	24·8	25·7	26·6	27·5	28·5	29·5	30·5	31·5	32·5	33·5	34·4
84·2	29	16·6	17·5	18·4	19·3	20·2	21	21·8	22·7	23·6	24·4	25·2	26·2	27·1	28·1	29·1	30·1	31·1	32·1	33·1	34
86·0	30	16·3	17·2	18·1	19	19·8	20·7	21·5	22·4	23·2	24	24·9	25·8	26·7	27·7	28·7	29·7	30·7	31·6	32·6	33·6

Temp.																					
Fahr.	Cent.	41 p.cent.	42 p.cent.	43 p.cent.	44 p.cent.	45 p.cent.	46 p.cent.	47 p.cent.	48 p.cent.	49 p.cent.	50 p.cent.	51 p.cent.	52 p.cent.	53 p.cent.	54 p.cent.	55 p.cent.	56 p.cent.	57 p.cent.	58 p.cent.	59 p.cent.	60 p.cent.
32·0	0	47·4	48·4	49·3	50·3	51·3	52·3	53·2	54·1	55·1	56·1	57·1	58	59	59·9	60·9	61·9	62·9	63·9	64·9	65·8
33·8	1	47	48	48·9	49·9	50·8	51·8	52·8	53·7	54·7	55·7	56·7	57·6	58·6	59·6	60·6	61·6	62·5	63·5	64·5	65·5
35·6	2	46·5	47·5	48·5	49·5	50·4	51·4	52·3	53·3	54·3	55·3	56·3	57·2	58·2	59·2	60·2	61·2	62·1	63·1	64·1	65·1
37·4	3	46·2	47·1	48·1	49	50	51	52	52·9	53·9	54·8	55·8	56·8	57·8	58·8	59·8	60·8	61·7	62·7	63·7	64·7
39·2	4	45·8	46·7	47·7	48·7	49·6	50·6	51·5	52·5	53·5	54·5	55·5	56·5	57·4	58·4	59·4	60·3	61·3	62·3	63·3	64·3
41·0	5	45·3	46·2	47·2	48·2	49·2	50·2	51·1	52·1	53·1	54	55	56	57	58	59	60	60·9	61·9	62·9	63·9
42·8	6	44·9	45·8	46·8	47·8	48·8	49·8	50·8	51·7	52·7	53·7	54·7	55·6	56·6	57·5	58·5	59·5	60·5	61·5	62·5	63·5
44·6	7	44·4	45·4	46·4	47·4	48·4	49·4	50·4	51·3	52·3	53·2	54·2	55·2	56·2	57·1	58·1	59·1	60·1	61·1	62·1	63·1
46·4	8	44	45	46	47	47·9	48·9	49·9	50·9	51·9	52·9	53·9	54·9	55·8	56·8	57·8	58·8	59·8	60·8	61·8	62·8
48·2	9	43·6	44·6	45·6	46·6	47·5	48·5	49·5	50·5	51·5	52·5	53·5	54·5	55·4	56·4	57·4	58·4	59·4	60·4	61·4	62·4
50·0	10	43·1	44·1	45·1	46·1	47·1	48·1	49·1	50·1	51·1	52	53	54	55	56	57	58	59	60	61	62
51·8	11	42·7	43·7	44·7	45·7	46·7	47·7	48·7	49·7	50·7	51·7	52·7	53·7	54·6	55·6	56·6	57·6	58·6	59·6	60·6	61·6
53·6	12	42·3	43·3	44·3	45·3	46·3	47·3	48·3	49·3	50·3	51·2	52·2	53·2	54·2	55·2	56·2	57·2	58·2	59·2	60·2	61·2
55·4	13	41·9	42·9	43·9	44·9	45·9	46·9	47·9	48·9	49·9	50·9	51·9	52·8	53·8	54·8	55·8	56·8	57·8	58·8	59·8	60·8
57·2	14	41·4	42·4	43·4	44·4	45·4	46·4	47·4	48·4	49·4	50·4	51·4	52·4	53·4	54·4	55·4	56·4	57·4	58·4	59·4	60·4
59·0	15	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
60·8	16	40·6	41·6	42·6	43·6	44·6	45·6	46·6	47·6	48·6	49·6	50·6	51·6	52·6	53·6	54·6	55·6	56·6	57·6	58·6	59·6
62·6	17	40·1	41·1	42·1	43·1	44·1	45·2	46·2	47·2	48·2	49·2	50·2	51·2	52·2	53·2	54·2	55·2	56·2	57·2	58·2	59·2
64·4	18	39·7	40·7	41·7	42·7	43·7	44·8	45·8	46·8	47·8	48·8	49·8	50·8	51·8	52·8	53·8	54·8	55·8	56·8	57·8	58·8
66·2	19	39·3	40·3	41·3	42·4	43·4	44·4	45·4	46·4	47·4	48·4	49·4	50·4	51·4	52·4	53·4	54·4	55·4	56·4	57·4	58·4
68·0	20	38·9	39·9	40·9	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
69·8	21	38·4	39·4	40·4	41·5	42·5	43·5	44·6	45·6	46·6	47·6	48·6	49·6	50·6	51·6	52·6	53·6	54·6	55·6	56·6	57·6
71·6	22	38	39	40	41·1	42·1	43·1	44·1	45·1	46·1	47·1	48·1	49·1	50·1	51·1	52·2	53·2	54·2	55·2	56·2	57·2
73·4	23	37·6	38·6	39·6	40·6	41·6	42·6	43·6	44·6	45·7	46·7	47·7	48·8	49·8	50·8	51·8	52·8	53·8	54·8	55·8	56·8
75·2	24	37·2	38·2	39·2	40·2	41·2	42·2	43·3	44·3	45·3	46·3	47·3	48·4	49·4	50·4	51·4	52·4	53·4	54·4	55·4	56·4
77·0	25	36·7	37·7	38·7	39·8	40·8	41·9	42·9	43·9	44·9	46	47	48	49	50	51	52	53	54	55	56
78·8	26	36·3	37·3	38·3	39·4	40·4	41·5	42·5	43·5	44·5	45·5	46·5	47·5	48·5	49·5	50·5	51·5	52·5	53·5	54·5	55·6
80·6	27	35·9	36·9	37·9	39	40	41·1	42·1	43·1	44·1	45·1	46·1	47·1	48·1	49·1	50·2	51·2	52·2	53·2	54·2	55·2
82·4	28	35·4	36·5	37·5	38·6	39·6	40·6	41·6	42·6	43·7	44·7	45·7	46·7	47·7	48·7	49·8	50·8	51·8	52·8	53·8	54·8
84·2	29	35	36	37·1	38·1	39·1	40·2	41·2	42·2	43·3	44·3	45·3	46·3	47·3	48·4	49·4	50·4	51·4	52·4	53·4	54·4
86·0	30	34·6	35·6	36·6	37·7	38·7	39·8	40·8	41·8	42·8	43.8	44·9	45·9	47	48	49	50	51	52	53	54

Temp.																					
Fahr.	Cent.	61 p.cent.	62 p.cent.	63 p.cent.	64 p.cent.	65 p.cent.	66 p.cent.	67 p.cent.	68 p.cent.	69 p.cent.	70 p.cent.	71 p.cent.	72 p.cent.	73 p.cent.	74 p.cent.	75 p.cent.	76 p.cent.	77 p.cent.	78 p.cent.	79 p.cent.	80 p.cent.
32·0	0	66·8	67·8	68·8	69·8	70·8	71·7	72·7	73·7	74·7	75·7	76·6	77·6	78·6	79·6	80·6	81·6	82·6	83·6	84·5	85·5
33·8	1	66·5	67·5	68·5	69·4	70·4	71·3	72·3	73·3	74·3	75·3	76·2	77·2	78·2	79·2	80·2	81·2	82·2	83·2	84·2	85·1
35·6	2	66·1	67·1	68·1	69·1	70·1	71	71·9	72·9	73·9	74·9	75·9	76·9	77·9	78·9	79·9	80·9	81·9	82·9	83·8	84·7
37·4	3	65·6	66·6	67·6	68·6	69·6	70·6	71·6	72·6	73·6	74·5	75·5	76·5	77·5	78·5	79·5	80·5	81·5	82·5	83·4	84·4
39·2	4	65·3	66·3	67·3	68·3	69·3	70·2	71·2	72·2	73·2	74·1	75·1	76·1	77·1	78·1	79·1	80·1	81·1	82·1	83	84
41·0	5	64·9	65·9	66·9	67·9	68·9	69·8	70·8	71·8	72·8	73·8	74·8	75·7	76·7	77·7	78·7	79·7	80·7	81·7	82·7	83·7
42·8	6	64·5	65·5	66·5	67·5	68·5	69·5	70·5	71·5	72·5	73·4	74·4	75·3	76·3	77·3	78·3	79·3	80·3	81·3	82·3	83·3
44·6	7	64·1	65·1	66·1	67·1	68·1	69·1	70·1	71·1	72	73	74	75	76	77	78	79	80	81	82	82·9
46·4	8	63·8	64·8	65·8	66·8	67·7	68·7	69·7	70·6	71·6	72·6	73·6	74·6	75·6	76·6	77·6	78·6	79·6	80·6	81·6	82·6
48·2	9	63·4	64·4	65·4	66·4	67·3	68·3	69·3	70·3	71·3	72·3	73·3	74·2	75·2	76·2	77·2	78·2	79·2	80·2	81·2	82·2
50·0	10	63	64	65	66	67	67·9	68·9	69·9	70·9	71·9	72·9	73·9	74·9	75·9	76·9	77·9	78·9	79·9	80·9	81·9
51·8	11	62·6	63·6	64·6	65·6	66·6	67·6	68·6	69·6	70·6	71·6	72·6	73·5	74·5	75·5	76·5	77·5	78·5	79·5	80·5	81·5
53·6	12	62·2	63·2	64·2	65·2	66·2	67·2	68·2	69·2	70·2	71·2	72·2	73·1	74·1	75·1	76·1	77·1	78·1	79·1	80·1	81·1
55·4	13	61·8	62·8	63·8	64·8	65·8	66·8	67·8	68·8	69·8	70·8	71·8	72·8	73 8	74·8	75·8	76·8	77·8	78·8	79·8	80·8
57·2	14	61·4	62·4	63·4	64·4	65·4	66·4	67·4	68·4	69·4	70·4	71·4	72·4	73·4	74·4	75·4	76·4	77·4	78·4	79·4	80·4
59·0	15	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
60·8	16	60·6	61·6	62·6	63·6	64·6	65·6	66·6	67·6	68·6	69·6	70·6	71·6	72·6	73·6	74·6	75·6	76·6	77·6	78·6	79·6
62·6	17	60·2	61·2	62·2	63·2	64·2	65·2	66·3	67·2	68·2	69·2	70·2	71·2	72·2	73·2	74·2	75·2	76·2	77·2	78·2	79·2
64·4	18	59·8	60·8	61·8	62·8	63·8	64·8	65·8	66·8	67·8	68·8	69·8	70·8	71·8	72·8	73·8	74·9	75·9	76·9	77·9	78·9
66·2	19	59·4	60·4	61·4	62·5	63·5	64·5	65·5	66·5	67·5	68·5	69·5	70·5	71·5	72·5	73·5	74·5	75·5	76·5	77·5	78·5
68·0	20	59	60	61	62	63	64	65·1	66·1	67·1	68·1	69·1	70·1	71·1	72·1	73·1	74·1	75·1	76·1	77·1	78·1
69·8	21	58·6	59·6	60·7	61·7	62·7	63·7	64·7	65·7	66·7	67·7	68·7	69·7	70·7	71·7	72·7	73·7	74·7	75·8	76·8	77·8
71·6	22	58·2	59·2	60·3	61·3	62·3	63·3	64·3	65·3	66·3	67·3	68·3	69·3	70·3	71·3	72·3	73·3	74·3	75·4	76·4	77·4
73·4	23	57·8	58·8	59·8	60·9	61·9	62·9	63·9	64·9	65·9	66·9	67·9	68·9	70	71	72	73	74	75	76	77
75·2	24	57·4	58·4	59·4	60·5	61·5	62·5	63·5	64·5	65·5	66·5	67·5	68·5	69·6	70·6	71·6	72·6	73·6	74·6	75·6	76·6
77·0	25	57	58	59	60·1	61·1	62·1	63·1	64·1	65·1	66·1	67·1	68·1	69 2	70·2	71·2	72·2	73·2	74·2	75·3	76·3
78·8	26	56·6	57·6	58·6	59·6	60·7	61·7	62·7	63·7	64·7	65·7	66·7	67·7	68·8	69·8	70·8	71·8	72·8	73·8	74·8	75·9
80·6	27	56·2	57·2	58·3	59·3	60·3	61·3	62·3	63·3	64·3	65·3	66·3	67·3	68·4	69·4	70·4	71·4	72·4	73·4	74·4	75·5
82·4	28	55·8	56·8	57·8	58·8	59·9	60·9	61·9	62·9	63·9	64·9	66	67	68	69·1	70·1	71·1	72·1	73·1	74·1	75·1
84·2	29	55·4	56·4	57·4	58·5	59·5	60·5	61·5	62·5	63·5	64·5	65·6	66·6	67·7	68·7	69·7	70·7	71·7	72·7	73·7	74·7
86·0	30	55	56	57·1	58·1	59·1	60·1	61·1	62·1	63·1	64·1	65·2	66·2	67·3	68·3	69·3	70·3	71·3	72·3	73·3	74·3

TABLE II.—Concluded.

Temp.		Observed per centage of the Alcoholometer.																			
Fahr.	Cent.	81 p.cent.	82 p.cent.	83 p.cent.	84 p.cent.	85 p.cent.	86 p.cent.	87 p.cent.	88 p.cent.	89 p.cent.	90 p.cent.	91 p.cent.	92 p.cent.	93 p.cent.	94 p.cent.	95 p.cent.	96 p. cent.	97 p. cent.	98 p. cent.	99 p. cent.	100 p. cent.
32·0	0	86·4	87·4	88·3	89·2	90·2	91·2	92·2	93·1	94	95	95·9	96·8	97·7	98·6	99·5	100·3	101·2			
33·8	1	86·1	87	88	89	89·9	90·8	91·8	92·8	93·7	94·6	95·6	96·5	97·4	98·3	99·2	100	100·9			
35·6	2	85·7	86·6	87·6	88·6	89·6	90·5	91·5	92·4	93·4	94·3	95·2	96·1	97	97·9	98·9	99·8	100·7			
37·4	3	85·3	86·3	87·3	88·3	89·2	90·2	91·2	92·1	93	94	94·9	95·8	96·7	97·7	98·6	99·5	100·4			
39·2	4	85	86	87	88	88·9	89·9	90·8	91·8	92·7	93·7	94·6	95·5	96·4	97·4	98·3	99·2	100·1	101		
41·0	5	84·7	85·6	86·6	87·6	88·5	89·5	90·5	91·4	92·4	93·3	94·3	95·2	96·2	97·1	98	98·9	99·8	100·7		
42·8	6	84·3	85·3	86·3	87·3	88·2	89·2	90·1	91	92	93	93·9	94·9	95·9	96·8	97·7	98·7	99·6	100·5		
44·6	7	83·9	84·9	85·9	86·9	87·9	88·8	89·8	90·7	91·7	92·6	93·6	94·6	95·6	96·5	97·4	98·4	99·3	100·2		
46·4	8	83·6	84·6	85·6	86·5	87·5	88·5	89·4	90·4	91·3	92·3	93·3	94·3	95·3	96·2	97·1	98·1	99	99·9		
48·2	9	83·2	84·2	85·2	86·2	87·1	88·1	89·1	90	91	92	93	94	95	95·9	96·8	97·8	98·7	99·7	100	
50·0	10	82·8	83·8	84·8	85·8	86·8	87·8	88·7	89·7	90·7	91·7	92·7	93·7	94·7	95·6	96·5	97·5	98·5	99·4	100·4	
51·8	11	82·5	83·4	84·4	85·4	86·4	87·4	88·4	89·4	90·4	91·4	92·4	93·3	94·3	95·3	96·2	97·2	98·2	99·1	100·1	
53·6	12	82·1	83·1	84·1	85	86	87	88	89	90	91	92	93	94	95	95·9	96·9	97·9	98·8	99·8	
55·4	13	81·8	82·8	83·8	84·8	85·7	86·7	87·7	88·7	89·7	90·7	91·7	92·7	93·7	94·6	95·6	96·6	97·6	98·6	99·5	
57·2	14	81·4	82·4	83·4	84·4	85·4	86·4	87·4	88·3	89·3	90·3	91·3	92·3	93·3	94·3	95·3	96·3	97·3	98·3	99·3	
59·0	15	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
60·8	16	80·6	81·6	82·6	83·6	84·6	85·6	86·6	87·6	88·6	89·6	90·7	91·7	92·7	93·7	94·7	95·7	96·7	97·7	98·7	99·7
62·6	17	80·2	81·2	82·2	83·2	84·2	85·2	86·2	87·2	88·2	89·3	90·3	91·3	92·4	93·4	94·4	95·4	96·4	97·4	98·5	99·5
64·4	18	79·9	80·9	81·9	82·9	83·9	84·9	85·9	86·9	87·9	88·9	89·9	91	92	93	94	95·1	96·1	97·1	98·2	99·2
66·2	19	79·5	80·5	81·6	82·6	83·6	84·6	85·6	86·6	87·6	88·6	89·6	90·7	91·7	92·7	93·7	94·8	95·8	96·9	97·9	98·9
68·0	20	79·1	80·1	81·2	82·2	83·2	84·2	85·2	86·2	87·2	88·2	89·2	90·3	91·3	92·4	93·4	94·5	95·5	96·6	97·6	98·6
69·8	21	78·7	79·7	80·8	81·8	82·8	83·8	84·8	85·9	86·9	87·9	88·9	90	91	92	93·1	94·1	95·2	96·3	97·3	98·4
71·6	22	78·4	79·4	80·4	81·4	82·4	83·4	84·4	85·5	86·5	87·6	88·6	89·6	90·7	91·8	92·8	93·9	94·9	96	97	98·1
73·4	23	78	79	80·1	81·1	82·1	83·1	84·1	85·1	86·1	87·2	88·3	89·3	90·4	91·4	92·4	93·5	94·6	95·7	96·7	97·8
75·2	24	77·6	78·6	79·7	80·7	81·7	82·7	83·7	84·7	85·7	86·8	87·9	88·9	90	91·1	92·1	93·2	94·3	95·3	96·4	97·5
77·0	25	77·3	78·3	79·3	80·3	81·3	82·3	83·4	84·4	85·4	86·5	87·5	88·6	89·7	90·7	91·8	92·9	93·9	95	96·1	97·2
78·8	26	76·9	77·9	78·9	79·9	80·9	81·9	82·9	84	85	86·1	87·2	88·2	89·3	90·4	91·5	92·5	93·6	94·7	95·8	97
80·6	27	76·5	77·5	78·5	79·5	80·5	81·6	82·6	83·6	84·7	85·7	86·8	87·9	89	90	91·1	92·2	93·3	94·4	95·5	96·7
82·4	28	76·1	77·1	78·2	79·2	80·2	81·3	82·3	83·3	84·3	85·4	86·5	87·5	88·6	89·7	90·8	91·9	93	94·1	95·2	96·4
84·2	29	75·7	76·8	77·8	78·8	79·8	80·9	81·6	83	84	85	86·1	87·2	88·2	89·3	90·4	91·6	92·7	93·8	94·9	96·1
86·0	30	75·3	76·4	77·4	78·4	79·4	80·5	81·5	82·6	83·6	84·7	85·8	86·9	87·9	89	90·1	91·2	92·4	93·5	94·6	95·8

Tralles' and **Gay-Lussac's** alcoholometers have been adopted in different countries; the first in Prussia, the latter in France and Sweden. They both give the per cent. of alcohol in volume. If it be desired to know the per cent. by weight, it may be ascertained from the per cent. in volume of the liquid at 60°, by the following

TABLE OF COMPARISON

Between the per cent. of alcohol by volume at 60°—Tralles'—and per cent. by weight.

Per cent.		Per cent.	
By volume.	By weight.	By weight.	By volume.
0	0·	0	0·
5	4·00	5	6·25
10	8·05	10	12·42
15	12·15	15	18·52
20	16·28	20	24·57
25	20·46	25	30·55
30	24·69	30	36·45
35	28·99	35	42·25
40	33·39	40	47·92
45	37·90	45	53·43
50	42·52	50	58·79
55	47·29	55	63·97
60	52·20	60	68·97
65	57·25	65	73·79
70	62·51	70	78·40
75	67·93	75	82·80
80	73·59	80	86·97
85	79·50	85	90·88
90	85·75	90	94·46
95	92·46	95	97·61
100	100·00	100	100·00

Knowing the per centage volume of alcohol in a liquid at any temperature, the same results are arrived at when such per centage is multiplied by the specific gravity of the pure anhydrous spirit at the normal thermometric degree—0·7939 in **Tralles'** tables, and 0·7947 in **Gay-Lussac's**—and dividing this product by the density of the liquid at the observed temperature. Subjoined is a

TABLE BY LÖWITZ,

Giving the per cent. of absolute alcohol by weight, from the specific gravity at 68°.

Per cent. of alcohol by weight.	Specific gravity at 68°.	Per cent. of alcohol by weight.	Specific gravity at 68°.	Per cent. of alcohol by weight.	Specific gravity at 68°.	Per cent. of alcohol by weight.	Specific gravity at 68°.
100	791	74	859	48	919	23	968
99	794	73	861	47	921	22	970
98	797	72	863	46	923	21	971
97	800	71	866	45	925	20	973
96	803	70	868	44	927	19	974
95	805	69	870	43	930	18	976
94	808	68	872	42	932	17	977
93	811	67	875	41	934	16	978
92	813	66	877	40	936	15	980
91	816	65	880	39	938	14	981
90	818	64	882	38	940	13	983
89	821	63	885	37	942	12	985
88	823	62	887	36	944	11	986
87	826	61	889	35	946	10	987
86	828	60	892	34	948	9	988
85	831	59	894	33	950	8	989
84	834	58	896	32	952	7	991
83	836	57	899	31	954	6	992
82	839	56	901	30	956	5	994
81	842	55	903	29	957	4	995
80	844	54	905	28	959	3	997
79	847	53	907	27	961	2	998
78	849	52	909	26	963	1	999
77	851	51	912	25	965	0	1000
76	853	50	914	24	966		
75	856	49	917				

When a scale of per cent. by weight is added to **Tralles'** alcoholometer, it sometimes bears the name of **Richter's** scale, in which, as in other cases, is often meant only per cent. by weight, without reference to his original alcoholometer, and which is less accurate.

Proof

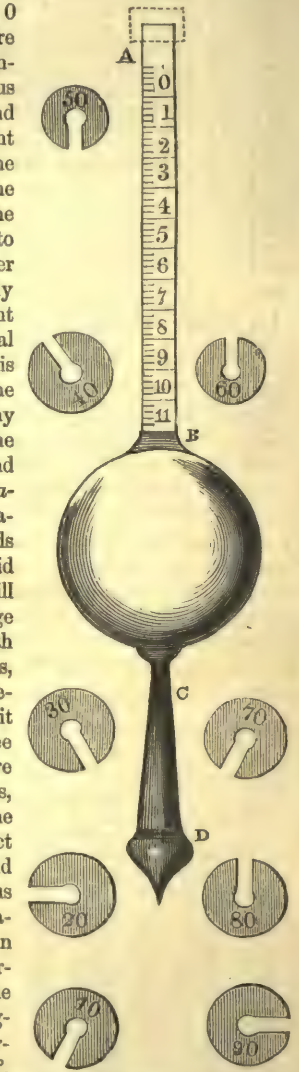
x

In England, the amount of revenue which flows into the Treasury annually, from the trade in spiritous liquors, renders it a matter of some importance to ascertain the real strength or per centage of alcohol with expedition and accuracy. To attain this object, various forms of alcoholometers have been constructed, some of which, as Sykes' hydrometer, have been sanctioned by the Excise board. This instrument does not at once note the specific gravity of the liquid, but the excess or deficiency of alcohol above or below a standard liquor called *proof spirit*—a term which originated in a rude method of ascertaining the strength of spirit, by pouring it upon some gunpowder in a dish, and igniting it. This was called the proof. If the gunpowder took fire at the end of the combustion, the alcoholic liquor was said to be above or over proof; but, on the other hand, if the powder did not take fire, the liquor was reputed to be below or under proof. The gunpowder test, however, is quite uncertain as to the quantity of spirit present in the liquid; for though the powder is ignited when a small portion is inflamed, yet, on employing a larger quantity, so much water is formed as to prevent the ignition. By parliamentary enactments, the strength of proof spirit has been fixed at such a density that thirteen volumes, at 51° Fahr., should equal in weight twelve volumes of water at the same temperature. According to this standard, proof spirit has a gravity of ·9186 at 60° Fahr., and contains 57·27 per cent. by volume, or 49·50 per cent. by weight, of absolute alcohol. The liquors are estimated at the quantity of spirit above or below this standard, as the case may be; and when a numeral is prefixed, it means the number of volumes that are to be added to or subtracted from a hundred volumes of the liquid, to bring it to standard or proof strength; thus, twenty-over-proof means that a hundred volumes of liquor require the addition of twenty of water to bring them to proof strength, and when a liquid is twenty-under-proof, it is understood that twenty parts of water are to be abstracted.

Sykes' hydrometer, a description of which follows, is constructed on this principle. This is selected for special illustration, partly on account of its being almost exclusively employed by the Revenue in this country, and partly from its simplicity.

It consists of a flat stem, A B—Fig. 82—3·4 inches long, which is divided on both sides into ten or sometimes eleven equal parts, and each of these subdivided into five, the scale being numbered from zero—0—to 11. The stem, A B, is soldered to a brass ball, 1·6 in. in diameter, into which is fixed a small conical stem, C D, 1·13 in. long; at the end of this is a pear-shaped loaded bulb, D, half an inch in diameter. The whole instrument is made of brass, and is 6·7 inches long. Nine circular weights accompany it, numbered 10, 20, 30, 40, *et cetera*, up to 90, and there is another weight in the form of a parallelopiped. Each of the circular weights is cut into the centre, so that they can be placed on the conical stem at C, and slid down to D; in consequence of the enlargement of the cone, they cannot slip off at D, but must be brought up to C for that purpose. The weight in the form of a parallelopiped has a square notch in one of its sides, by which it can be placed on the summit, A, of the stem. In using this instrument, it is immersed in the spirit, and pressed with the finger till sunk to zero, or 0; from the resistance felt, it will be easy to judge which weight will be required to append to it. After slipping on the weight at C, the instrument is again immersed into the liquid, and pressed with the hand till it has descended to 0 on the scale; the pressure of the hand is then withdrawn, and the apparatus is allowed to emerge and settle at the proper point of the density of the liquid, as indicated by the scale and weights. The figure on the scale to which the hydrometer sinks is now carefully observed, and the weight placed upon the conical stem added thereto; this sum, on referring to the tables which accompany the instrument, where the same number is found under the column *indication*, and to the temperature which corresponds with that of the liquid under examination, will give the per centage of alcohol. The strength is expressed in numbers, denoting the excess or deficiency per cent. of spirit in any sample. Three sliding rules, which are used instead of the tables, likewise accompany the hydrometer. The exact temperature of the liquid should be taken previous to ascertaining the gravity, as the difference in temperature, if not corrected, would give, as the result, a weaker or stronger liquor than if the thermometer stood at 60°. When Excise officers use this instrument, they are instructed to take the nearest degree above the mercury, when it stands between any two degrees of the thermometer, as also the next division below the surface of the liquid, when it marks the instrument between any two lines, thereby giving whatever advantage the difference would occasion, in favor of the trader or manufacturer. The square weight or cap shows the difference between the weight of proof spirit and that of water, as described in the first clause of the hydrometer act, being one-twelfth part of the weight of the

Fig. 82.



x In use from 5th January 1817 by act of Parliament.

hydrometer when loaded with the weight 60. If this weight be placed on the top of the stem at A, and the hydrometer be loaded with the weight 60, it will sink in distilled water, at the temperature of 51°, to the proof point, P, marked on the narrow edge of the stem.

The following will serve as examples to show how the strength of the spiritous liquid is ascertained:—

Example 1.—Suppose the temperature of the solution to be 47°, and that the weight, 60, is required to sink the stem of the hydrometer to 8, which, when added to the weight 60, will give 68; then, under the temperature 47°, and in a line with the marginal indication, section 60, 68 is observed, which shows that the liquor is ten and a half under proof.

Example 2.—If the stem of the instrument, when loaded with 50, sinks to 5, and the temperature, as shown by the thermometer, is 45° Fahr., then, in the marginal section headed 50, 55—equal to the weight 50, and the indication on the divided stem—is found; and under the temperature 45°, the noted strength is 10·6 per cent. over proof.

The following are two out of fifty pages in a book given with the instrument:—

40° TO 50° TEMPERATURE. WEIGHT 50.

Indication.	Temperature of the spirits by Fahrenheit's thermometer.											Indication.
	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	
50	19·2	18·9	18·6	18·3	18·0	17·7	17·3	17·0	16·7	16·4	16·1	50
·2	18·9	18·6	18·3	18·0	17·7	17·4	17·0	16·7	16·4	16·1	15·8	·2
·4	18·7	18·3	18·0	17·7	17·4	17·1	16·8	16·4	16·1	15·8	15·5	·4
·6	18·4	18·1	17·8	17·5	17·2	16·9	16·5	16·2	15·9	15·6	15·3	·6
·8	18·2	17·8	17·5	17·2	16·9	16·6	16·3	15·9	15·6	15·3	15·0	·8
51	17·9	17·5	17·2	16·9	16·6	16·3	16·0	15·6	15·3	15·0	14·7	51
·2	17·6	17·2	16·9	16·6	16·3	16·0	15·7	15·3	15·0	14·7	14·4	·2
·4	17·3	16·9	16·6	16·3	16·0	15·7	15·4	15·1	14·7	14·4	14·1	·4
·6	17·1	16·7	16·4	16·1	15·8	15·5	15·2	14·8	14·5	14·2	13·9	·6
·8	16·8	16·4	16·1	15 8	15·5	15·2	14·9	14·6	14·2	13·9	13 6	·8
52	16·5	16·1	15·8	15·5	15·2	14·9	14·6	14·3	13·9	13·6	13·3	52
·2	16·2	15·8	15·5	15·2	14·9	14·6	14·3	14·0	13·6	13·3	13·0	·2
·4	15·9	15·5	15·2	14·9	14·6	14·3	14·0	13·7	13·3	13·0	12·7	·4
·6	15·6	15·3	15·0	14·7	14·4	14·1	13·7	13·4	13·1	12·8	12·5	·6
·8	15·3	15·0	14·7	14·4	14·1	13·8	13·4	13·1	12·8	12·5	12·2	·8
53	15·0	14·7	14·4	14·1	13·8	13·5	13·1	12·8	12·5	12·2	11·9	53
·2	14·7	14·4	14·1	13·8	13·5	13·2	12·8	12·5	12·2	11·9	11·6	·2
·4	14·4	14·1	13·8	13·5	13·2	12·9	12·5	12·2	11·9	11·6	11 3	·4
·6	14·2	13·9	13·6	13·3	13·0	12·7	12·3	12·0	11·7	11·4	11 1	·6
·8	13·9	13·6	13.3	13·0	12·7	12·4	12·0	11·7	11·4	11·1	10·8	·8
54	13·6	13·3	13·0	12·7	12·4	12·1	11·7	11·4	11·1	10·8	10·5	54
·2	13·3	13·0	12·7	12·4	12·1	11·8	11·4	11·1	10·8	10·5	10·2	·2
·4	13·0	12·7	12·4	12·1	11·8	11·5	11·1	10·8	10·5	10·2	9·9	·4
·6	12·8	12·5	12·2	11·8	11·5	11·2	10·9	10·6	10·2	9·9	9·6	·6
·8	12·5	12·2	11·9	11·5	11·2	10·9	10·6	10·3	9·9	9·6	9·3	·8
55	12·2	11·9	11·6	11·2	10·9	10·6	10·3	10·0	9·6	9·3	9·0	55
·2	11·9	11·6	11·3	10·9	10·6	10·3	10·0	9·7	9·3	9·0	8·7	·2
·4	11·6	11·3	11·0	10·6	10·3	10·0	9·7	9·4	9·0	8·7	8·4	·4
·6	11·3	11·0	10·7	10·4	10·1	9·7	9·4	9·1	8·8	8·5	8·1	·6
·8	11·0	10·7	10·4	10·1	9·8	9·4	9·1	8·8	8·5	8·2	7·8	·8
56	10·7	10·4	10·1	9·8	9·5	9·1	8·8	8·5	8·2	7·9	7·5	56
·2	10·4	10·1	9·8	9·5	9·2	8·8	8·5	8·2	7·9	7·6	7·2	·2
·4	10·1	9·8	9·5	9·2	8·9	8·5	8·2	7·9	7·6	7·3	6·9	·4
·6	9·9	9·6	9·3	9·0	8·6	8·3	7·9	7·6	7·3	7·0	6·7	·6
·8	9·6	9·3	9·0	8·7	8·3	8·0	7·6	7·3	7·0	6·7	6·4	·8
57	9·3	9·0	8·7	8·4	8·0	7·7	7·3	7·0	6·7	6·4	6·1	57
·2	9·0	8·7	8·4	8·1	7·7	7·4	7·0	6·7	6·4	6·1	5·8	·2
·4	8·7	8·4	8·1	7·8	7·4	7·1	6·7	6·4	6·1	5·8	5·5	·4
·6	8·4	8·1	7·8	7·5	7·2	6·8	6·5	6·1	5·8	5·5	5·2	·6
·8	8·1	7·8	7·5	7.2	6·9	6·5	6·2	5·8	5·5	5·2	4·9	·8
58	7·8	7·5	7·2	6·9	6·6	6·2	5·9	5·5	5·2	4·9	4·6	58
·2	7·5	7·2	6·9	6·6	6·3	5·9	5·6	5·2	4·9	4·6	4·3	·2
·4	7·2	6·9	6·6	6·3	6·0	5·6	5·3	4·9	4·6	4·3	4·0	·4
·6	6·9	6·6	6·3	5·9	5·7	5·3	5·0	4·7	4·3	4·0	3·7	·6
·8	6·6	6·3	6·0	5·6	5·4	5·0	4·7	4·4	4·0	3·7	3·4	·8
59	6·3	6·0	5·7	5·3	5·1	4·8	4·4	4·1	3·7	3·4	3·1	59
·2	6·0	5·7	5·4	5·0	4·8	4·4	4·1	3·8	3·4	3·1	2·8	·2
·4	5·7	5·4	5·1	4·7	4·5	4·1	3·8	3·5	3·1	2·8	2·5	·4
·6	5·4	5·1	4·8	4·4	4·1	3·8	3·5	3·2	2·8	2·5	2·1	·6
·8	5·1	4·8	4·5	4·1	3·8	3·5	3·2	2·9	2·5	2·2	1·8	·8
60	4·8	4·5	4·2	3·8	3·5	3·2	2·9	2·6	2·2	1·9	1·5	60
Indication.	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	Indication.
	Temperature of the spirits by Fahrenheit's thermometer.											

WEIGHT 60. TEMPERATURE 40° TO 50°.

Indication.	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	Indication.
	Temperature of the spirit by Fahrenheit's thermometer.											
60	4·8	4·5	4·2	3·8	3·5	3·2	2·9	2·6	2·2	1·9	1·5	60
·2	4·5	4·2	3·9	3·5	3·2	2·9	2·6	2·3	1·9	1·6	1·2	·2
·4	4·2	3·9	3·6	3·2	2·9	2·6	2·3	2·0	1·6	1·3	·9	·4
·6	3·9	3·6	3·3	2·9	2·6	2·3	2·0	1·7	1·3	1·0	·6	·6
·8	3·6	3·3	3·0	2·6	2·3	2·0	1·7	1·4	1·0	·7	·3	·8
61	3·3	3·0	2·7	2·3	2·0	1·7	1·4	1·1	·7	.4	·0	61
·2	3·0	2·7	2·4	2·0	1·7	1·4	1·1	·8	·4	·1	·3	·2
·4	2·7	2·4	2·1	1·7	1·4	1·1	·8	·5	·1	·2	·6	·4
·6	2·4	2·1	1·8	1·4	1·1	·8	·4	·1	·3	·6	·9	·6
·8	2·1	1·8	1·5	1·1	·8	·5	·1	·2	·6	·9	1·2	·8
62	1·8	1·5	1·2	·8	·5	·2	·2	·5	·9	1·2	1·5	62
·2	1·5	1·2	·9	·5	·2	·1	·5	·8	1·2	1·5	1·8	·2
·4	1·2	·9	·6	·2	·1	·4	·8	1·1	1·5	1·8	2·1	·4
·6	·8	·5	·2	·2	·5	·8	1·1	1·5	1·8	2·2	2·5	·6
·8	·5	·2	·1	·5	·8	1·1	1·4	1·8	2·1	2·5	2·8	·8
63	·2	·1	·4	·8	1·1	1·4	1·7	2·1	2·4	2·8	3·1	63
·2	·1	·4	·7	1·1	1·4	1·7	2·0	2·4	2·7	3·1	3·4	·2
·4	·4	·7	1·0	1·4	1·7	2·1	2·4	2·7	3·0	3·4	3·7	·4
·6	·8	1·1	1·4	1·8	2·1	2·4	2·7	3·1	3·4	3·8	4·1	·6
·8	1·1	1·4	1·7	2·1	2·4	2·8	3·1	3·4	3·7	4·1	4·4	·8
64	1·4	1·7	2·0	2·4	2·7	3·1	3·4	3·7	4·0	4·4	4·1	64
·2	1·7	2·0	2·3	2·7	3·0	3·4	3·7	4·0	4·3	4·7	5·6	·2
·4	2·0	2·3	2·6	3·0	3·3	3·7	4·1	4·4	4·7	5·1	5·4	·4
·6	2·4	2·7	3·0	3·4	3·7	4·1	4·4	4·7	5·0	5·4	5·7	·6
·8	2·7	3·0	3·3	3·7	4·0	4·4	4·8	5·1	5·4	5·8	6·1	·8
65	3·0	3·3	3·6	4·0	4·3	4·7	5·1	5·4	5·7	6·1	6·4	65
·2	3·3	3·6	3·9	4·3	4·6	5·0	5·4	5·7	6·0	6·4	6·7	·2
·4	3·6	4·0	4·3	4·7	5·0	5·4	5·7	6·1	6·4	6·8	7·1	·4
·6	4·0	4·3	4·6	5·0	5·3	5·7	6·1	6·4	6·7	7·1	7·4	·6
·8	4·3	4·7	5·0	5·4	5·7	6·1	6·4	6·8	7·1	7·5	7·8	·8
66	4·6	5·0	5·3	5·7	6·0	6·4	6·7	7·1	7·4	7·8	8·1	66
·2	5·0	5·3	5·7	6·0	6·3	6·7	7·0	7·4	7·7	8·1	8·4	·2
·4	5·3	5·7	6·0	6·4	6·7	7·1	7·4	7·8	8·1	8·5	8·8	·4
·6	5·7	6·0	6·4	6·7	7·0	7·4	7·7	8·1	8·4	8·8	9·1	·6
·8	6·0	6·4	6·7	7·1	7·4	7·8	8·1	8·5	8·8	9·2	9·5	·8
67	6·4	6·7	7·1	7·4	7·7	8·1	8·4	8·8	9·1	9·5	9·8	67
·2	6·7	7·0	7·4	7·7	8·0	8·4	8·7	9·1	9·4	9·8	10·1	·2
·4	7·1	7·4	7·8	8·1	8·4	8·8	9·1	9·5	9·8	10·2	10·5	·4
·6	7·4	7·7	8·1	8·4	8·7	9·1	9·4	9·8	10·1	10·5	10·8	·6
·8	7·8	8·1	8·5	8·8	9·1	9·5	9·8	10·2	10·5	10·9	11·2	·8
68	8·1	8·4	8·8	9·1	9·4	9·8	10·1	10·5	10·8	11·2	11·5	68
·2	8·5	8·8	9·1	9·4	9·8	10·2	10·5	10·9	11·2	11·6	11·9	·2
·4	8·8	9·1	9·5	9·8	10·1	10·5	10·8	11·2	11·5	11·9	12·2	·4
·6	9·2	9·5	9·8	10·1	10·5	10·9	11·2	11·6	11·9	12·3	12·6	·6
·8	9·5	9·8	10·2	10·5	10·8	11·2	11·5	11·9	12·2	12·6	12·9	·8
69	9·9	10·2	10·5	10·8	11·2	11·6	11·9	12·3	12·6	13·0	13·3	69
·2	10·3	10·6	10·9	11·2	11·6	12·0	12·3	12·7	13·0	13·4	13·7	·2
·4	10·6	10·9	11·2	11·5	11·9	12·3	12·6	13·0	13·3	13·7	14·0	·4
·6	11·0	11·3	11·6	11·9	12·3	12·7	13·0	13·4	13·7	14·1	14·4	·6
·8	11·3	11·6	11·9	12·2	12·6	13·0	13·3	13·7	14·0	14·4	14.7	·8
70	11·7	12·0	12·3	12·6	13·0	13·4	13·7	14·1	14·4	14·8	15·1	70
Indication.	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	Indication.
	Temperature of the spirit by Fahrenheit's thermometer.											

A modification of Sykes' hydrometer has been recently adapted for the testing of alcoholic liquors. It is constructed of glass, and is in the shape of an ordinary hydrometer, the stem being divided into degrees from 1 to 100: it carries a small delicate spirit thermometer in the bulb, to which a scale is affixed, having references from 0° to 12°, corresponding to FAHRENHEIT'S scale from 32° to 80°. The temperature of the menstrua is indicated by the small thermometer; and the calculations in the tables accompanying the instrument are made to accord with these numbers. There are tables supplied with the hydrometer, which are headed by the degrees and half degrees of the thermometric scale; and the corresponding content of spirit over or under proof at the respective degree of the table is placed opposite each degree of the hydrometer.

When the instrument is used to ascertain the value of a liquid, the degree of immersion, and also that of the thermometer are noted; on referring to the table headed by the observed temperature, the per centage of spirit over or under proof is found opposite the degree to which the hydrometer sunk in the liquid.

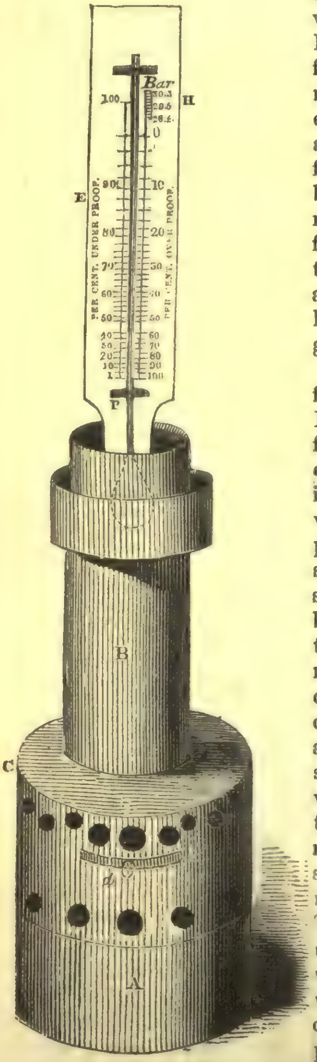
By Sykes' hydrometer, the specific gravity of the spirit indicating proof strength is ·9200. Ure has constructed a table, appended below, wherein the specific gravity corresponds to the strength noted by the hydrometer, whether over or under proof strength.

CORRESPONDENCE BETWEEN THE SPECIFIC GRAVITIES AND PER CENTS. OF ALCOHOL OVER PROOF AT 60° FAHRENHEIT.

Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. under proof.	Specific gravity.	Per cent. under proof.
0·8156	67·0	0·8410	54·2	0·8657	39·3	0·8912	21·9	0·9178	1·9	0·9445	21·9	0·9722	58·3
8160	66·8	8413	54·1	8660	39·1	8915	21·7	9182	1·6	9448	22·2	9726	59·0
8163	66·6	8417	53·9	8664	38·9	8919	21·4	9185	1·3	9452	22·7	9730	59·7
8167	66·5	8420	53·7	8667	38·7	8922	21·2	9189	1·0	9456	23·1	9734	60·4
8170	66·3	8424	53·5	8671	38·4	8926	20·9	9192	0·7	9460	23·5	9738	61·1
8174	66·1	8427	53·3	8674	38·2	8930	20·6	9196	0·3	9464	23·9	9742	61·8
8178	65·6	8431	53·1	8678	38·0	8933	20·4	9200	Proof.	9468	24·3	9746	62·5
8181	65·8	8434	52·9	8681	37·8	8937	20·1	Under	proof.	9472	24·7	9750	63·2
8185	65·6	8438	52·7	8685	37·6	8940	19·9	9204	0·3	9476	25·1	9754	63·9
8188	65·5	8441	52·5	8688	37·3	8944	19·6	9207	0·6	9480	25·5	9758	64·6
8192	65·3	8445	52·3	8692	37·1	8948	19·3	9210	0·9	9484	25·9	9762	65·3
8196	65·1	8448	52·1	8695	36·9	8951	19·1	9214	1·3	9488	26·3	9766	66·0
8199	65·0	8452	51·9	8699	36·7	8955	18·8	9218	1·6	9492	26·7	9770	66·7
8203	64·8	8455	51·7	8702	36·4	8959	18·6	9222	1·9	9496	27·1	9774	67·4
8206	64·7	8459	51·5	8706	36·2	8962	18·3	9226	2·2	9499	27·5	9778	68·0
8210	64·5	8462	51·3	8709	35·9	8966	18·0	9229	2·5	9503	28·0	9782	68·7
8214	64·3	8465	51·1	8713	35·7	8970	17·7	9233	2·8	9507	28·4	9786	69·4
8218	64·1	8469	50·9	8716	35·5	8974	17·5	9237	3·1	9511	28·8	9790	70·1
8221	64·0	8472	50·7	8720	35·2	8977	17·2	9241	3·4	9515	29·2	9794	70·8
8224	63·8	8476	50·5	8723	35·0	8981	16·9	9244	3·7	9519	29·7	9798	71·4
8227	63·6	8480	50·3	8727	34·7	8985	16·6	9248	4·0	9522	30·1	9802	72·1
8231	63·4	8482	50·1	8730	34·5	8989	16·4	9252	4·4	9526	30·6	9806	72·8
8234	63·2	8486	49·9	8734	34·3	8992	16·1	9255	4·7	9530	31·0	9810	73·5
8238	63·1	8490	49·7	8737	34·1	8996	15·9	9259	5·0	9534	31·4	9814	74·1
8242	62.9	8493	49·5	8741	33·8	9000	15·6	9263	5·3	9539	31·1	9818	74·8
8245	62·7	8496	49·3	8744	33·6	9004	15·3	9267	5·7	9542	32·3	9822	75·4
8249	62·5	8499	49·1	8748	33·4	9008	15·0	9270	6·0	9546	32·8	9826	76·1
8252	62·3	8503	48·9	8751	33·2	9011	14·8	9274	6·4	9550	33·2	9830	76·7
8256	62·2	8506	48·7	8755	32·9	9015	14·5	9278	6·7	9553	33·7	9834	77·3
8259	62·0	8510	48·5	8758	32·7	9019	14·2	9282	7·0	9557	34·2	9838	78·0
8263	61·8	8513	48.3	8762	32·4	9023	13·9	9286	7·3	9561	34·7	9842	78·6
8266	61·6	8516	48·0	8765	32·2	9026	13·6	9291	7·7	9565	35·1	9846	79·2
8270	61·4	8520	47·8	8769	32·0	9030	13·4	9295	8·0	9569	35·6	9850	79·8
8273	61·3	8523	47·6	8772	31·7	9034	13·1	9299	8·3	9573	36·1	9854	80·4
8277	61·1	8527	47·4	8776	31·5	9038	12·8	9302	8·6	9577	36·6	9858	81·1
8280	60·9	8530	47·2	8779	31·2	9041	12·5	9306	9·0	9580	37·1	9862	81·7
8284	60·7	8533	47·0	8783	31·0	9045	12·2	9310	9·3	9584	37·6	9866	82·3
8287	60·5	8537	46·8	8786	30·8	9049	12·0	9314	9·7	9588	38·1	9870	82·9
8291	60·4	8540	46·6	8790	30·5	9052	11·7	9318	10·0	9592	38·6	9874	83·5
8294	60·2	8543	46·4	8793	30·3	9056	11·4	9322	10·3	9596	39·1	9878	84·0
8298	60·0	8547	46·2	8797	30·0	9060	11·1	9326	10·7	9599	39·6	9882	84·6
8301	59·8	8550	46·0	8800	29·8	9064	10·8	9329	11·0	9603	40·1	9886	85·2
8305	59·6	8553	45·8	8804	29·5	9067	10·6	9332	11·4	9607	40·6	9890	85·8
8308	59·5	8556	45·6	8807	29·3	9071	10·3	9337	11·7	9611	41·1	9894	86·3
8312	59·3	8560	45·4	8811	29·0	9075	10·0	9341	12·1	9615	41·7	9898	86·9
8315	59·1	8563	45·2	8814	28·8	9079	9·7	9345	12·4	9619	42·2	9902	87·4
8319	58·9	8566	45·0	8818	28·5	9082	9·4	9349	12·8	9623	42·8	9906	88·0
8322	58·7	8570	44·8	8822	28·3	9085	9·2	9353	13·1	9627	43·3	9910	88·5
8326	58·6	8573	44·6	8825	28·0	9089	8·9	9357	13·5	9631	43·9	9914	89·1
8329	58·4	8577	44·4	8829	27·8	9093	8·6	9360	13·9	9635	44·4	9918	89·6
8333	58·2	8581	44·2	8832	27·5	9097	8·3	9364	14·2	9638	45·0	9922	90·2
8336	58·0	8583	43·9	8836	27·3	9100	8·0	9368	14·6	9642	45·5	9926	90·7
8340	57·8	8587	43·7	8840	27·0	9104	7·7	9372	14·9	9646	46·1	9930	91·2
8344	57·7	8590	43·5	8843	26·8	9107	7·4	9376	15·3	9650	46·7	9934	91·7
8347	57·5	8594	43·3	8847	26·5	9111	7·1	9380	15·7	9654	47·3	9938	92·3
8351	57·3	8597	43·1	8850	26·3	9115	6·8	9384	16·0	9657	47·9	9942	92·8
8354	57·1	8601	42·8	8854	26·0	9118	6·5	9388	16·4	9661	48·5	9946	93·3
8358	56·9	8604	42·6	8858	25·8	9122	6·2	9392	16·7	9665	49·1	9950	93·8
8362	56·8	8608	42·4	8861	25·5	9126	5·9	9396	17·1	9669	49·7	9954	94·3
8365	56·6	8611	42·2	8865	25·3	9130	5·6	9399	17·5	9674	50·3	9958	94·9
8369	56·4	8615	42·0	8869	25·0	9134	5·3	9403	17·8	9677	51·0	9962	95·4
8372	56·2	8618	41·7	8872	24·8	9137	5·0	9407	18·2	9681	51·6	9966	95·9
8376	56·0	8622	41·5	8876	24·5	9141	4·8	9411	18·5	9685	52·2	9970	96·4
8379	55·9	8625	41·3	8879	24·3	9145	4·5	9415	18·9	9689	52·9	9974	96·8
8383	55·7	8629	41·1	8883	24·0	9148	4·2	9419	19·3	9693	53·3	9978	97·3
8386	55·5	8632	40·9	8886	23·8	9152	3·9	9422	19·7	9697	54·2	9982	97·7
8390	55·3	8636	40·6	8890	23·5	9156	3·6	9426	20·0	9701	54·8	9986	98·2
8393	55·1	8639	40·4	8894	23·2	9159	3·3	9430	20·4	9705	55·5	9990	98·7
8396	55·0	8643	40·2	8897	23·0	9163	3·0	9434	20·8	9709	56·2	9993	99·1
8400	54·8	8646	40·0	8901	22·7	9167	2·7	9437	21·2	9713	56·9	9997	99·6
8403	54·6	8650	39·8	8904	22·5	9170	2·4	9441	21·6	9718	57·6	1·0000	100·0
8407	54·4	8653	39·6	8908	22·2	9174	2·1						

Although it had long been known that the boiling point of water was raised by holding in solution neutral salts and other bodies, and although many experiments were instituted with the view of ascertaining the proportion of salts or sugar present in liquids, still the application of this fact to the determination of the quantity of alcohol in spiritous liquors was reserved for the **Abbé Brossard-Vidal**, of Toulon, who ascertained that the boiling point of such liquors was in direct proportion to the quantity of alcohol they contained, irrespective of any amount of saline ingredients present in them. When certain salts are added to dilute alcohol, such as carbonate of potassa or chloride of calcium, which are capable of abstracting a portion of the water, the boiling point of the solution is lowered, instead of the reverse being the case. On these principles the **Abbé** constructed his apparatus, whereby the Revenue Boards of France might furnish themselves with ready proof if the wines entered were genuine, as it was frequently found that brandy had been passed under the name of wine, and a fraud thus committed, the duty on alcoholic and strong spiritous liquors being much greater than on wine.

Fig. 83



These principles also formed the basis of Mr. **Field's** alcoholometer for the determination of the quantity of spirit in liquors, and for which he obtained a patent in 1847. It consisted originally of a spirit lamp, surmounted by a boiler containing the liquid to be examined, and a large cylindrical glass bulb containing mercury, and having an upright stem, whose calibre was such as to allow the expansion of the mercury to elevate a small glass float which rested on its surface. This float was connected by a thread with a similar bead, which hung in the open air; the thread passed over a pulley which, turning with the motion of the beads, caused the index to move along the circular graduated scale. This instrument was much improved by Dr. **Ure**, who introduced, instead of the cylindrical bulb and beads, a thermometer attached to a graduated scale. Fig. 83 shows the improved instrument.

A is the spirit lamp, surrounded by an outer coating containing cold water for keeping the lamp cool, should many experiments be required to be made in succession; B the boiler, which fits into the cage, C, in the case of the lamp; a damper, *d*, modifies or extinguishes the heat of the lamp when required; E is the thermometer with a very small bore, after the manner of **Wollaston's** instrument for determining the height of mountains by the boiling point of water on their summit. The bottom of the scale on the ebullition thermometer is marked P, for proof, on the left side, and 100—proof spirit—on the right side. It corresponds with 178·6 Fahr., nearly, or the boiling point of alcohol, spec. grav. ·920.

From the mean of a great number of experiments, **Ure** drew up the following table, which shows the boiling point of alcohol of various specific gravities:—

Temperature Fahr.	Specific gravity.		
178·5	0·9200	—	Proof.
179·75	0·9321	10	Under proof.
180·4	0·9420	20	“
182·01	0·9516	30	“
183·40	0·960	40	“
185·6	0·9665	50	“
189·0	0·9729	60	“
191·8	0·9786	70	“
196·4	0·9850	80	“
202·0	0·992	90	“

When spirit is over proof, the variation of the boiling point is so small that a strictly accurate result cannot conveniently be obtained, and, in fact, proof spirit, or spirit approaching to that strength, is more accurately tested by diluting it with its own bulk of water, before ascertaining the strength, and then doubling the result. Another source of error pointed out by **Ure**, is the elevation of the boiling point, when the liquor is kept heated for any length of time; it is, however, nearly obviated by the addition of common salt to the solution in the boiler of the apparatus, in the proportion of thirty-five or forty grains. This substance has the curious property of arresting the mercury in the thermometer at the boiling point of the wine, spirit, or beer, submitted to examination, and thus offers a means by which a proper reading can be made. In order to correct the difference arising from a higher or lower pressure of the atmosphere, distilled water should be boiled in the apparatus, and the temperature noted; for the boiling point of the alcoholic solutions will vary as that of the water, when the pressure of the atmosphere is greater or less. In order to correct this source of error, a subsidiary barometrical scale, H, is attached to the thermometer, E. The method of using the alcoholometer is as follows:—

The lamp, A, is lighted; B is filled to about one inch from the top with the liquid to be examined, to which a paper of common salt is added, and the whole is then placed on the lamp, A; and lastly, the thermometer, E, is fixed to the scale, with its bulb immersed in the liquid. Before commencing general operations for the day, the boiler, B, is filled with water, and boiled; if the column of mercury remains at 29·5, which is placed opposite to 100 on the scale at the left hand—the mean boiling point of water—no correction is required to be made; but if it stands higher or lower than this figure, the various boiling points of the samples bear reference to this. In testing the solutions, when the mercury begins to rise out of the bulb of the thermometer, the damper is to be pushed in midway into the groove to lower the heat. As the liquid boils freely, the mercury in the tube will become stationary, and the figure on the left indicates the per centage under proof, while that on the right shows the per centage over proof. **Field**'s alcoholometer only tells the quantity of alcohol, but an auxiliary experiment with the hydrometer will readily give the specific gravity, and upon reference to Table I., the amount of saccharine and extractive matter is ascertained. In testing wines, the specific gravity of the liquid is first taken, then the boiling point ascertained by the alcoholometer, and the corresponding specific gravity deducted from that previously found by the hydrometer; the difference will, upon referring to Table II., show the quantity of extractive and saccharine matter in a hundred gallons of the liquid. For example, if the specific gravity by the hydrometer be ·989, and that by the alcoholometer shows the presence of alcohol of sixty-nine and six-tenths, whose specific gravity is ·979 by the tables, deduct the latter gravity from the gravity of the bulk, or ·989, and a difference of ten remains, which number, upon reference to Table II., will give twenty-five pounds of saccharine and extractive matter in a hundred gallons, combined with thirty gallons and four-tenths of proof spirit. Should the barometer of the day mark any other indication above or below the standard 29·5, the thermometer scale will then only show the apparent strength, and reference must be had to the small ivory indicator, it being the counterpart of the barometrical scale of the thermometer; thus, if the barometer indicate 30, place 30 of the indicator against the boiling point of the liquid, and opposite the line of 29·5 will be found the true strength.

Example 1.—Barometer at 30.—Suppose the mercury to stop at the same point, 72 U.P.; place 30 of the indicator against 72 on the thermometer, and the line 28·5 will cut 69·6 U.P., the true per centage.

Example 2.—Barometer at 29.—Suppose the mercury to stop at the same point, 72 U.P.; place 29 of the indicator against 72 on the thermometer, and the line 29·5 will cut 74·3 U.P., the true strength.

To ascertain the strength of malt liquors and their respective values, the instrument has been furnished with a glass saccharometer, testing glass, and slide rule. Commence by charging the test glass with the liquid, then insert the saccharometer to ascertain the present gravity or density per barrel, and at whatever number it floats, that will indicate the number of pounds per barrel the liquor is heavier than water:—

Example 1.—Suppose the saccharometer to float at the figure 8, which would indicate eight pounds per barrel; then submit the liquid to the boiling test, with an addition of salt to arrest the mercury at the proper boiling point of the liquid, as before mentioned; now, suppose it should show—the barometrical difference being accounted for—90 U.P., that would be equivalent to ten per cent. of proof alcohol. Refer to the slide scale, and place A on the slide against 10 on the upper line of figures, and facing B on the lower line will be 18, showing that eighteen pounds per barrel have been decomposed to constitute that per centage of spirit; then, by adding eighteen pounds to the present eight pounds per barrel, the result will be twenty-six pounds, the original weight of the wort after leaving the copper.

Example 2.—The saccharometer marks ten pounds per barrel, and at the boiling point it indicates 88 U.P., equivalent to 12 gallons of proof spirit per cent.; place A against 12, and opposite B will be 21½, the number of pounds per barrel, which, when added to the ten pounds present, will give a total of thirty-one and a half pounds.

To ascertain the relative value.—Suppose the price of the twenty-six pounds beer to be thirty-six shillings per barrel, and the thirty-one pounds beer to be forty shillings—to ascertain which beer will be the cheaper, place 26 on the opposite side of the rule against 36, and opposite 31½ pounds will be forty-three shillings and seven pence, showing that the latter beer is cheaper by three shillings and seven pence per barrel. By this instrument the quantity of spirit per cent. in distiller's wort, whether it be in progress of fermentation or ready for the still, is indicated, the only difference being in the allowances in the sliding rule. Saccharometers applicable to the foregoing rules for beer, ale, *et cetera*, have been adjusted at the temperature of 60° Fahr., and will be found correct for general purposes; but where extreme minuteness is required, the variation of temperature must be taken into account, and for every ten degrees of temperature above 60°, three-tenths of a pound must be added to the gross amount found by the slide rule; on the contrary, for every ten degrees below 60°, three-tenths of a pound must be deducted.

For Cordialized Spirits.—The operation in this instance is different from that applied to the testing of beers, which have the alcohol generated in the worts; for in cordialized spirits of every kind, the alcohol is the original, and the saccharine matter, or sugar, is an addendum. If a hundred gallons of spirit are required of a given strength—say fifty per cent. under proof—fifty gallons of proof spirit to which fifty gallons of water are added, will be of this strength, and upon testing it by the alcoholometer, it will be found as correct as by the hydrometer. But in cordializing spirit, the reverse is the case; for to the fifty gallons of spirit, proof strength, fifty gallons of sugar and water would be added, thereby rendering the hydrometer useless, excepting for taking the specific gravity of the bulk, and, according to the quantity of sugar present, so a relative quantity of water must have been displaced; and as the sugar has no reducing properties, the alcoholometer will only show the strength of the cordial in relation to the quantity of water contained in it, as the principle indicates, irrespective of the saccharine or extractive matter. Suppose, in making one hundred gallons of cordial at 50 U.P., three pounds of sugar are put to the gallon, or three hundred pounds to the hundred gallons, these three hundred pounds displacing 18·67 gallons of water, only 31·33 gallons of the water, instead of fifty, have been applied; the sugar, without reducing properties, making up the bulk of one hundred gallons, which is meant to represent fifty per cent. U.P.

The alcoholometer will only show at the full point of ebullition the alcoholic strength in relation to the water in one hundred gallons of the mixture, or thirty-five per cent. U.P., leaving fifteen per cent. to be accounted for in the bulk. As the quantity of sugar present must be determined before that per centage can be arrived at, a double object will be effected by so doing, namely, eliciting in all instances the quantity of sugar present, as well as the per centage of spirit to be accounted for; as an example, suppose the specific gravity of a cordial is 1·076, then submit the liquid to the boiling point, and having ascertained the per centage of alcohol—thirty-five U.P.—the specific gravity of alcohol at that strength will be found to be 0·956; deduct 0·956 from the specific gravity of the bulk, or 1·076, and ·120 will remain; refer that to its amount in the head line of Table II., namely, 120, under which will be found 3, representing three pounds of sugar to the gallon; and by running the eye down its column to opposite the alcoholic strength indicated—thirty-five U.P.—will be found 14·9, representing the water displaced by the sugar, and which amount added to 35 per cent. ascertained, makes the total upon the bulk 49·9 per cent. U.P., with three pounds of sugar to the gallon.

TABLE I.

Table of specific gravities by Sykes' hydrometer, adapted to Field's patent alcoholometer for cordialized spirits.

Temperature, 60°.—Specific gravity of water, 1·000°.

60		70		80		90		100		110		120		130		140		150		160		170		180	
Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.
60	922	70	942	80	961	90	981	100	1000	110	1020	120	1041	130	1063	140	1085	150	1107	160	1129	170	1152	180	1175
1	924	1	943	1	963	1	983	1	1002	1	1022	1	1044	1	1065	1	1087	1	1109	1	1131	1	1155	1	1178
2	926	2	945	2	965	2	985	2	1004	2	1024	2	1046	2	1067	2	1089	2	1111	2	1134	2	1157	2	1180
3	928	3	947	3	967	3	987	3	1006	3	1026	3	1048	3	1069	3	1091	3	1113	3	1136	3	1159	3	1182
4	930	4	949	4	969	4	989	4	1008	4	1029	4	1050	4	1071	4	1093	4	1116	4	1139	4	1162	4	1185
5	932	5	951	5	971	5	991	5	1010	5	1031	5	1052	5	1074	5	1096	5	1118	5	1141	5	1164	5	1187
6	934	6	953	6	973	6	993	6	1012	6	1033	6	1054	6	1076	6	1098	6	1120	6	1143	6	1166	6	1189
7	936	7	955	7	975	7	995	7	1014	7	1035	7	1056	7	1078	7	1100	7	1123	7	1145	7	1168	7	1191
8	938	8	957	8	977	8	997	8	1016	8	1037	8	1058	8	1080	8	1102	8	1125	8	1148	8	1171	8	1194
9	940	9	959	9	979	9	999	9	1018	9	1039	9	1061	9	1082	9	1104	9	1127	9	1150	9	1173	9	1196
70	942	80	961	90	981	100	1000	110	1020	120	1041	130	1063	140	1085	150	1107	160	1129	170	1152	180	1175	190	1199

TABLE II.

Table showing the lbs. of sugar per gallon in cordialized spirits, with the per centages to be added to the indicated strength, per the alcoholometer.

Difference of gravity. Lbs. of sugar per gallon.		10 4 oz. or 25 to 100.	15 6 oz. 37½ to 100.	20 8 oz. 50 to 100.	25 10 oz. 62½ to 100.	30 12 oz. 75 to 100.	35 14 oz. 87½ to 100.	40 1·0	45 oz. 1·2	50 oz. 1·4	Difference of gravity. Lbs. of sugar per gallon.	
Sp. grav. of spirit.	Per cent. of spirit.										Per cent. of spirit.	Sp. grav. of spirit.
920	Proof.	1·6	2·5	3·4	4·4	5·3	6·2	7·1	8·1	9·0	Proof.	920
923	2·5	1·6	2·5	3·3	4·3	5·2	6·1	6·9	7·8	8·8	2·5	923
926	5·	1·5	2·4	3·2	4·2	5·0	5·9	6·8	7·7	8·6	5·	926
929	7·5	1·5	2·3	3·2	4·1	4·9	5·8	6·6	7·5	8·4	7·5	929
932	10·	1·4	2·2	3·1	4·0	4·8	5·7	6·5	7·4	8·2	10·	932
935	12·5	1·4	2·2	3·1	3·9	4·7	5·5	6·3	7·2	8·0	12·5	935
938	15·	1·4	2·1	3·0	3·8	4·6	5·4	6·2	7·0	7·8	15·	938
940	17·5	1·3	2·1	2·9	3·7	4·5	5·3	6·0	6·8	7·6	17·5	940
943	20·	1·3	2·0	2·8	3·6	4·4	5·2	5·9	6·7	7·5	20·	943
945	22·5	1·3	2·0	2·7	3·5	4·3	5·0	5·7	6·5	7·3	22·5	945
948	25·	1·2	1·9	2·6	3·4	4·1	4·8	5·5	6·3	7·0	25·	948
950	27·5	1·2	1·9	2·5	3·3	4·0	4·7	5·3	6·1	6·8	27·5	950
952	30·	1·1	1·8	2·4	3·1	3·8	4·5	5·1	5·8	6·5	30·	952
954	32·5	1·1	1·7	2·3	3·0	3·6	4·3	4·8	5·5	6·2	32·5	954
956	35·	1·0	1·6	2·2	2·9	3·5	4·1	4·6	5·3	6·0	35·	956
958	37·5	1·0	1·6	2·1	2·8	3·4	3·9	4·4	5·1	5·8	37·5	958
960	40·	·9	1·5	2·0	2·7	3·2	3·8	4·3	4·9	5·5	40·	960
962	42·5	·9	1·5	2·0	2·6	3·1	3·6	4·1	4·7	5·3	42·5	962
964	45·	·9	1·4	1·9	2·5	3·0	3·5	4·0	4·6	5·1	45·	964
965	47·5	·8	1·4	1·9	2·4	2·9	3·4	3·9	4·4	4·9	47·5	965
967	50·	·8	1·3	1·8	2·3	2·8	3·3	3·8	4·3	4·8	50·	967
969	52·5	·7	1·2	1·7	2·2	2·6	3·1	3·6	4·1	4·5	52·5	969
970	55·	·7	1·2	1·6	2·0	2·4	2·9	3·4	3·8	4·2	55·	970
972	57·5	·6	1·1	1·5	1·9	2·2	2·7	3·1	3·5	3·9	57·5	972
973	60·	·6	1·0	1·4	1·8	2·1	2·5	2·9	3·3	3·6	60·	973
974	62·5	·6	1·0	1·3	1·7	2·0	2·4	2·7	3·1	3·5	62·5	974
976	65·	·5	·9	1·2	1·5	1·8	2·2	2·5	2·8	3·1	65·	976
977	67·5	·5	·8	1·1	1·4	1·7	2·0	2·3	2·6	2·9	67·5	977
979	70·	·4	·7	1·0	1·3	1·5	1·8	2·1	2·4	2·6	70·	979
980	72·5	·4	·7	·9	1·1	1·3	1·6	1·9	2·1	2·3	72·5	980
982	75·	·3	·6	·8	1·0	1·2	1·4	1·6	1·8	2·0	75·	982
983	77·5	·3	·5	·7	·9	1·0	1·2	1·4	1·6	1·8	77·5	983
984	80·	·2	·4	·6	·8	·9	1·0	1·2	1·4	1·6	80·	984
986	82·5	·2	·3	·5	·7	·8	·9	1·0	1·2	1·4	82·5	986
988	85·	·2	·2	·4	·6	·7	·8	·9	1·0	1·2	85·	988
990	87·5	·1	·2	·3	·5	·6	·7	·8	·9	1·0	87·5	990
992	90·	·1	·1	·2	·4	·5	·6	·7	·8	·9	90·	992
994	92·5	..	·1	·2	·3	·4	·5	·6	·7	·8	92·5	994
996	95·	..	..	·1	·2	·3	·4	·5	·6	·7	95·	996
998	97·5	..	..	..	·1	·2	·3	·4	·5	·6	97·5	998

Table I., which shows the specific gravity on the bulk of the mixture, bears reference to the table following it —Table II. of the alcoholometer.

In estimating the density of various gins and cordials, suppose the specific gravity of the liquid is found to be ·957, and by the boiling point it proves to be 14 U.P., whose specific gravity is ·937; when this is deducted from the former—·957—the remainder is 20, under which, in Table II. will be found ½, or one-half pound of sugar to the gallon; and, on observing the opposite 14 U.P., 3·0 will be found, which, added to 14, makes the total on the bulk 17 per cent. U.P., with fifty pounds of sugar to the hundred gallons.

Care must be taken that the mercury is entirely in the bulb of the thermometer before it is fixed to the stem for operation; and the salt must be added in all cases when determining the boiling point, except for water.

The instrument is highly advantageous by proving the relative quantity of fruit or *saccharum*, and alcohol, requisite to constitute the normal wine of each species.

Some beers possess the remarkable power of causing drowsiness and stupor, without a corresponding previous exhilaration, and on this account may be justly suspected of having been sophisticated with *cocculus indicus*, opium, or some analogous drug; and this suspicion may become certainty if they be shown by the alcoholometer to contain only a few per cent. of fermented spirit.—*Ure.*

Fownes's paper on the value, in absolute alcohol, of spirits of different specific gravities, is ingenious and valuable; the leading features of it are therefore quoted.

The table was formed synthetically; absolute alcohol and distilled water were weighed out in the required proportions, mixed in small closely-stopped bottles, and well shaken together. After standing three or four days, the mixtures were brought to the temperature of 60° Fahr. exactly, and their specific gravities determined with great care. When two or three days more had elapsed, this last-named operation was repeated, but in no case was it observed that any further contraction had occurred. Neither was the specific gravity of a mixture, containing nearly equal parts alcohol and water, which had been so examined, changed by being enclosed in a strong accurately-stoppered bottle, and heated for some time to a temperature above its boiling point.

In this manner, every alternate number in the table —every even number—was obtained by direct experiment; the others were then incorporated. When completed, the table was examined by various methods calculated to test its accuracy, but no error of sufficient magnitude to limit its usefulness was detected.

The absolute alcohol employed in these experiments, was prepared in the following manner:—The strongest rectified spirit was agitated with half its weight of carbonate of potassa, deprived of water of crystallization, and left in contact with it for some days. It was then decanted upon half its weight of powdered quicklime, made from black marble, contained in a metal still, which could be perfectly closed. The mixture of spirit and lime was retained in a warm situation for a week or thereabouts, and then distilled by means of a water-bath. By this treatment the specific gravity of the alcohol was reduced to 0·796, or even below, and by a repetition of the process of digestion with powdered lime, and redistillation, the last traces of water were removed. In this manner, without difficulty, the very considerable quantity of absolute alcohol required for the experiments was procured. Absolute alcohol thus obtained, has the specific gravity ·7938 at 60° Fahr.; it is extremely expansible by heat, which renders the determination of its exact specific gravity difficult and troublesome when the temperature of the room is either above or below 60°. The same remark applies to the mixtures of alcohol and water extending over more than half the table, the most minute precautions regarding temperature being necessary to avoid serious errors. In a glass retort containing pieces of copper foil, absolute alcohol boils at 177° Fahr., the barometer standing at 29·75 inches. Lastly, when analyzed by combustion with oxide of copper, it yields numbers representing the proportion of carbon and hydrogen present, so closely agreeing with those required by theory as to leave no doubt of its purity and freedom from all admixture.

TABLE OF THE PROPORTION BY WEIGHT

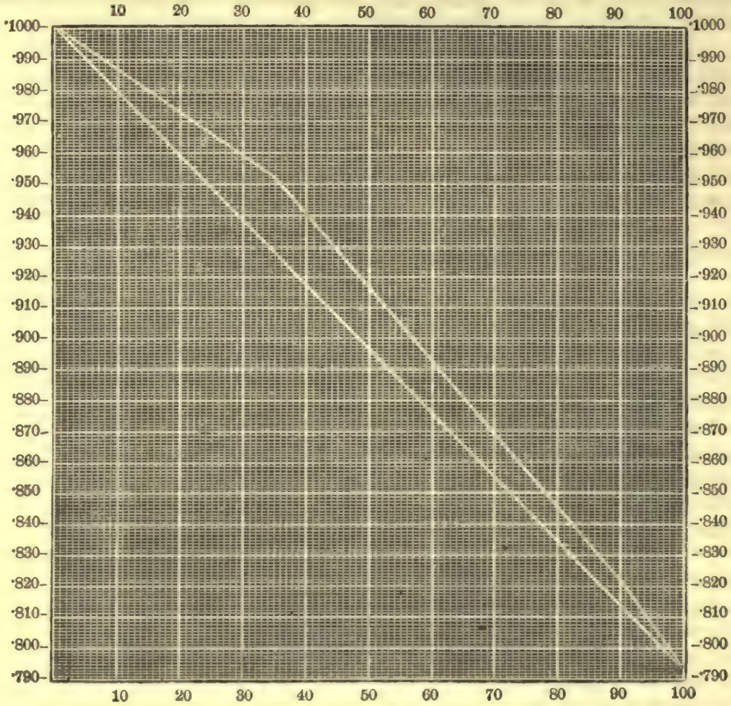
Of real or absolute alcohol contained in 100 parts of spirits of different specific gravities, at the temperature of 60° Fahr.

Specific gravity.	Per centage of alcohol.	Specific gravity.	Per centage of alcohol.	Specific gravity.	Per centage of alcohol.
·9991	0·5	·9511	34	·8769	68
·9981	1	·9490	35	·8745	69
·9965	2	·9470	36	·8721	70
·9947	3	·9452	37	·8696	71
·9930	4	·9434	38	·8672	72
·9914	5	·9416	39	·8649	73
·9898	6	·9396	40	·8625	74
·9884	7	·9376	41	·8603	75
·9869	8	·9356	42	·8581	76
·9855	9	·9335	43	·8557	77
·9841	10	·9314	44	·8533	78
·9828	11	·9292	45	·8508	79
·9815	12	·9270	46	·8483	80
·9802	13	·9249	47	·8459	81
·9789	14	·9228	48	·8434	82
·9778	15	·9206	49	·8408	83
·9766	16	·9184	50	·8382	84
·9753	17	·9160	51	·8357	85
·9741	18	·9135	52	·8331	86
·9728	19	·9113	53	·8305	87
·9716	20	·9090	54	·8279	88
·9704	21	·9069	55	·8254	89
·9691	22	·9047	56	·8228	90
·9678	23	·9025	57	·8199	91
·9665	24	·9001	58	·8172	92
·9652	25	·8979	59	·8145	93
·9638	26	·8956	60	·8118	94
·9623	27	·8932	61	·8089	95
·9609	28	·8908	62	·8061	96
·9593	29	·8886	63	·8031	97
·9578	30	·8863	64	·8001	98
·9560	31	·8840	65	·7969	99
·9544	32	·8816	66	·7938	100
·9528	33	·8793	67		

The contraction of volume suffered by various mixtures of alcohol and water, may be rendered obvious by comparing the actual specific gravities of such mixtures, with their calculated mean densities. In the accompanying engraving, in which the vertical lines represent the per centage of alcohol by weight, and the horizontal lines the specific gravities, the calculated mean specific gravities of the mixtures are seen to form a straight diagonal line from corner to corner, while the actual densities form an irregular curve with upward convexity, rising quickly to near its maximum deviation at 30 per cent., running almost parallel with the other line to 50 per cent., and thence declining until it reaches the extremity of the scale.

Fig. 84.

COMPARISON OF MEAN AND ACTUAL SPECIFIC GRAVITIES OF VARIOUS MIXTURES OF ALCOHOL AND WATER.



Silbermann's observations on a new instrument for ascertaining, by the amount of dilatation, the relative quantities of two liquids when mixed, and particularly mixtures of alcohol and water, are well worth transcribing. He states that various means have been suggested and employed for ascertaining the respective quantities of alcohol and water in mixtures of those liquids; but these are all found to possess many disadvantages. The distillation process is rarely employed on account of the great skill required in its application, and the length of time the operation demands before the results are arrived at. This method, at best, is only applied where accurate and scientific truth is required, irrespective of delay and toil. The density test is open to error on account of sirupy and other extractive matters being present, which would render the specific gravity of the impregnated liquid higher than that of alcohol, and thus prevent the true amount of spirit from being determined with strict accuracy; hence the Excise duty is, in consequence, evaded. Wines, tested by the density process, only indicate about one-half their strength; and for this reason **Gay-Lussac** combines, with the use of his alcoholometric areometer, the distillation test.

The boiling test of Field's hydrometer is likewise open to objections; for it is a known fact that steam, or vapor, may be heated beyond its point of generation, and that the thermometer, even when immersed in the liquid, may, under certain circumstances, stand several degrees above the real temperature, which would give rise to a difference in result of four alcoholometric degrees for every such extra indication. Besides, it is necessary to take the barometric variations into account in some better way than has hitherto been done. **Silbermann's** arrangement is said to obviate the evils attendant on those methods hitherto employed, and is based upon the dilatation of the alcoholic liquid. It is well known that between zero and 100° C.—212° Fahr.—of temperature, the dilatation of alcohol is triple that of water. This is much greater between 25° and 50° C.—45° and 90° Fahr.—and may thus be demonstrated:—Pour water at 45° Fahr. into a thermometer tube, so as to fill the reservoir, and a small portion of the tube up to a certain mark; then, on heating the thermometer to 90° Fahr. the water will rise a certain distance above the mark, and let this point be scratched on the tube; now, if the same quantity of pure alcohol, also at 45° Fahr., be substituted for the water, and heated to the temperature of 90°, it will be found to have risen three and a half times higher than the water. Any mixture of alcohol and water, on being treated in the same way, will be found to have a mean point of dilatation between these two, and will be nearer the one or the other, according as either liquid preponderates in the mixture. If, therefore, a series of mixtures of alcohol and water be made, beginning with—

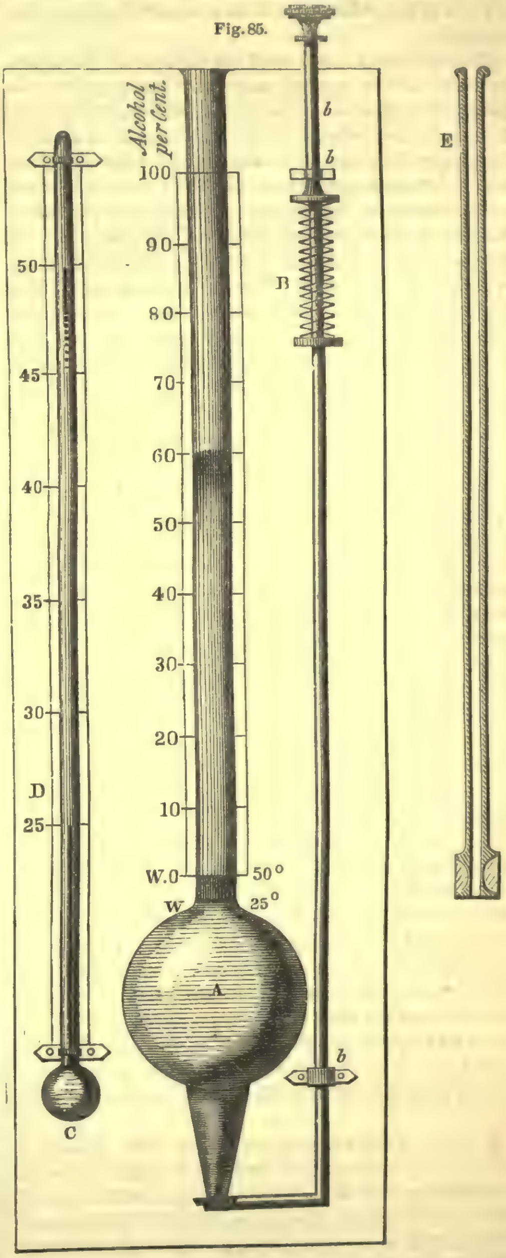
Water	100 parts,	Alcohol	0 parts;
do.	99 "	do.	1 "
do.	98 "	do.	2 "

and so on up to pure alcohol; and their several points of elevation at the respective temperatures, 45° and 90° Fahr., be carefully marked on the tube, a complete centesimal alcoholometric scale will be produced, which will indicate the quantity of alcohol contained in any mixture of alcohol and water, by introducing it at 45° and heating it to 90° Fahr.

The same process may be employed with regard to any other two liquids having points of dilatation differing between those of alcohol and water; but it will be understood that the same scale will not serve for more than one mixture. To adapt this principle to the ordinary purposes of alcoholometric measurement, **Silbermann** constructed a thermometer in a peculiar manner, thereby forming an instrument which he named a *dilatometer*, a view of which is presented to the reader in Fig. 85. The instrument is made by Messrs. **Casartelli**, of Liverpool and Manchester, who kindly furnished the drawing.

The form and arrangement of this apparatus are as follow:—A large bulb tube, A, of the form of a hydrometer, but tapering at the bottom and open at the top, is fixed to a metal plate, to which a thermometer, C, is also attached. The thermometer is graduated from 25° to 50° C.—45° to 90° F.—this being the working temperature of the dilatometer. Both the thermometer, and bulb of the apparatus, A, are immersed in the liquor to be tested; the former, to show the temperature, and the latter, to ascertain the expansion of the liquid when it is heated from 25° to 50° C. The expansion of distilled water between the extreme degrees of the thermometer, is marked on the stem of A by the figures 25 and 50; from the latter, the scale of degrees from 1 to 100 appended to the stem of the apparatus commences, and by it, the expansion of the alcoholic liquors is ascertained, when such liquors are heated from 25° to 50°. A valve of cork, or india-rubber, closes the tapering end of A; this valve is attached to a rod, *b b*, fastened to the supporting plate and connected to a spring, B. To cause the liquid under examination to flow, the spring valve is depressed by turning a screw of four threads, for the purpose of giving a quick motion, fitting in the upper part of the rod, and by reversing the motion of the screw the thermometer is closed; sometimes the rod may be made to terminate in a flattened end or cap, as the figure represents, and is moved by pressing it with the finger. As the liquids are often impregnated with air or gas, it is found necessary, before testing, to drive it off; the best method of effecting this is by means of a vacuum, which may be produced by the use of a small leather piston, E, working in the tube of the thermometer. This piston serves first, by suction, to fill the thermometer from below; and then, the lower part being closed, and the piston driven down, on raising it the air will be seen to separate from the liquid at all points; and after two or three more strokes of the piston the liquid may be completely purified, so that no more bubbles will rise during the operation to disturb the proper level of the column. To effect the withdrawal of the piston without any shock, so as not to divide the column abruptly, the piston-rod is made hollow throughout; the operator, having wetted his finger, applies it to the top of the piston-rod, in order to create a vacuum as he draws up the piston; he then withdraws it to readmit the air, and the piston is thus removed without a shock.

Fig. 85.



In order to form the vacuum properly, the liquid must be pumped in, until it rises to the piston-rod; on depressing the piston there is no air left underneath it.

The tube is now full of liquid, and by depressing the spring valve the liquid is run off, until it is as high as the lowest mark on the tube, when the temperature has been for two or three minutes at the lowest degree of the mercury thermometer. The inventor proposed this method to overcome the inconveniences to which those in general use are liable, and also as admitting of being applied to test wines as well as alcoholic liquors of any strength.

The method is based upon the principle of dilatation, and any salts or vegetal substances entering into the composition of, or otherwise present in wines or alcoholic liquors, do not materially affect the result, as all solutions expand in the same degree as water within the range of temperature which has been chosen. There is no occasion to fear the presence of any liquid more dilatable than alcohol, as liquids of such a nature are more expensive, and may, besides, be detected by their peculiar taste and smell. The same reasoning is also applicable to liquids less dilatable than water. The initial temperature, 25° C.—45° F.—was selected, because water may always be found below that temperature in summer. The final degree, 50° C.—90° F.—was chosen to avoid the effect of evaporation, which might diminish the actual degree if it approached too near the boiling point; and the range between this and 25° C.—45° F.—was found sufficient. Besides, these two points offer great facilities for the experiment, as, if it be conducted in a vessel containing about a quart of water, a small spirit lamp underneath it will be sufficient to maintain either the one or the other. The plate carrying the thermometers serves to agitate the water, that its temperature may be uniform throughout.

In Pennsylvania, Dicas' Liverpool patent hydrometer is adopted by Act, 15th of April, 1835, for the inspection of domestic distilled liquors. It is made of copper, with a stem pointed on the summit to receive brass poises, and is accompanied by a graduated ivory scale, with a sliding rule and thermometer to make corrections for temperature. By this instrument the strength of the spirit is indicated, as with Sykes' hydrometer, by a certain number above or below proof. The Act determines the standard of proof spirits to be as follows:—*If the liquor be hydrometer proof, or one hundred parts of spirit and one hundred parts of water, it shall be marked as liquor of the fourth proof; if it should be* 5° *below hydrometer proof, it shall be marked as of the third proof; if the liquor shall be* 10° *below hydrometer proof, it shall be marked as of the second proof; if the liquor shall be* 15° *below hydrometer proof, it shall be marked as of the first proof.—Booth.*

The proof spirit, which is, according to the preceding, composed of equal parts of alcohol and water, possesses a specific gravity, according to Ure, of 0·9218 at 60° Fahr., and is centesimally composed of 55·76 of alcohol, and 44·24 of water by volume, or, by weight, of 48·03 of alcohol, and 51·97 of water.

The alcoholometer of Tralles is used in Russia, those of Cartiers and Gay-Lussac in France—all of which determine the per centage by volume of alcohol in a liquid, and by means of the calculation which is given in the foregoing, the per centage by weight is obtained. Having the per centage of alcohol by weight in a liquid, the quantity of water is likewise found by deducting the amount of alcohol from a hundred; but if the content of alcohol be determined per volume, this rule will not answer, since, on mixing alcohol and water, a contraction in volume takes place. Thus, if to fifty volumes of alcohol, fifty of water be added, the mixture will not make up a hundred volumes. In the distillation of spirit it is often necessary to reduce stronger alcoholic liquors to lower degrees of strength; and unless the amount of contraction be known, considerable labour will be attendant on bringing the mixture to the desired quality. The following table shows the relative volumes of alcohol and water which, when mixed, make up a hundred.

100 Volumes of spirit contain at 59°.		100 Volumes of spirit contain at 59°.	
Volume of alcohol.	Volume of water.	Volume of alcohol.	Volume of water.
100	0·00	45	58·64
95	6·18	40	63·44
90	11·94	35	68·14
85	17·47	30	72·72
80	22·87	25	77·24
75	28·19	20	81·72
70	33·14	15	86·20
65	38·615	10	90·72
60	43·73	5	95·31
55	48·77	0	100·00
50	53·745		

The annexed table of Gay-Lussac is more extensive on the subject, and shows the volume of water per cent. which is to be added to a liquor, of whatever strength, to bring it to any degree of dilution.

In this table the top horizontal column indicates the per centage by volume of the spirit which is required to be produced. The vertical columns under the top line specify the number of volumes of water which are to be added to a thousand volumes of alcohol, the richness of which is pointed out in the vertical column at the left-hand side of the table, in order to obtain the spirit properly diluted.

As illustrations facilitate the comprehension of the student in every problem, it may be well to follow the rule in this instance, and give a few examples taken from the table, in order that its application throughout may be more effectually understood. If it be required to prepare an alcohol of fifty per cent. from a liquor which is eighty per cent., the number, fifty, is sought in the top horizontal line of strengths, and in the vertical line under this figure the number six hundred and thirty-one is found in a horizontal line with eighty in the left hand vertical column; this figure indicates the number of volumes of water which are to be added to a thousand volumes of alcohol of eighty per cent. to bring it to the required degree of dilution.

Again, if it be requisite to bring a spirit of sixty per cent. to thirty per cent., the latter figure is found in the horizontal column at the top, and in the vertical column under it, in a line with sixty on the left hand, one thousand and seventeen is seen, which is the number of measures of water indispensable to reduce a thousand volumes of the strong liquor to the strength of thirty per cent.

TABLE OF GAY-LUSSAC FOR PROCURING A WEAKER ALCOHOL OF A CERTAIN STRENGTH FROM A STRONGER.

1000 vols. of alcohol of per cent. by vol.	Desired strength of the spirit.																			
	Per cent. by volume.																			
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
31	33																			
32	67	32																		
33	100	65	31																	
34	134	97	63	30																
35	167	129	94	61	30															
36	201	162	126	91	59	29														
37	234	194	157	122	89	58	28													
38	268	227	189	153	119	86	56	27												
39	302	260	220	183	148	115	84	55	27											
40	335	292	252	214	178	144	112	82	53	26										
41	369	325	284	245	208	173	140	109	80	52	25									
42	403	358	315	275	238	202	169	137	107	78	51	25								
43	437	390	347	306	268	231	197	164	134	104	76	50	24							
44	471	423	379	337	298	261	225	192	160	130	102	75	49	24						
45	505	456	411	368	328	290	254	220	187	157	127	99	73	47	23					
46	539	489	443	399	358	319	282	247	214	183	153	124	97	71	46	23				
47	573	522	474	430	388	348	310	275	241	209	179	149	122	95	70	46	22			
48	607	555	506	461	418	377	339	303	268	235	204	174	146	119	93	68	45	22		
49	641	588	538	492	448	407	367	330	295	262	230	200	171	143	116	91	67	44	21	
50	675	621	570	523	478	436	396	358	322	288	256	225	195	167	140	114	89	66	43	21
51	709	654	602	554	508	465	424	386	349	314	281	250	220	191	163	137	112	87	64	42
52	743	687	634	585	539	495	453	414	376	341	307	275	244	215	187	160	134	110	86	63
53	777	720	666	616	569	524	482	442	403	367	333	300	269	239	210	183	157	132	107	84
54	811	753	699	647	599	553	510	469	431	394	359	325	293	263	234	206	179	153	129	105
55	846	786	731	679	629	583	539	497	458	420	385	350	318	287	257	229	202	176	151	127
56	880	820	763	700	660	613	568	525	485	447	411	376	343	311	281	252	224	198	172	148
57	914	853	795	741	690	642	596	553	512	473	436	401	367	335	305	275	247	220	194	169
58	949	886	827	772	721	672	625	581	540	500	462	426	392	359	328	298	269	242	216	190
59	983	919	860	804	751	701	654	609	567	527	488	452	417	384	352	321	292	264	237	212
60	1017	953	892	835	781	731	683	637	594	553	514	477	442	408	375	345	315	286	259	233
61	1052	986	924	867	812	760	711	665	622	580	540	503	467	432	399	368	338	309	281	254
62	1086	1019	957	898	842	790	740	694	649	607	566	528	491	456	423	391	360	331	303	276
63	1121	1053	989	929	873	820	769	722	676	633	593	554	516	481	447	414	383	353	325	297
64	1155	1086	1022	961	904	850	798	750	704	660	619	579	541	505	471	438	406	376	346	318
65	1190	1120	1054	992	934	879	827	778	731	687	645	605	566	529	494	461	429	398	368	340
66	1224	1153	1086	1024	965	909	856	806	759	714	671	630	591	554	518	484	451	420	390	361
67	1259	1187	1119	1055	995	939	885	834	786	741	697	656	616	578	542	508	474	443	412	383
68	1293	1220	1151	1087	1026	969	914	863	814	767	723	681	641	603	566	531	497	465	434	404
69	1328	1254	1184	1118	1056	998	943	891	841	794	750	707	666	627	590	554	520	487	456	426
70	1363	1287	1216	1150	1087	1028	972	919	869	821	776	732	691	652	614	578	543	510	478	447
71	1397	1321	1249	1182	1118	1058	1001	948	897	848	802	758	716	676	638	601	566	532	500	469
72	1432	1354	1282	1213	1149	1088	1030	977	924	875	828	784	741	701	662	625	589	555	522	491
73	1467	1388	1314	1245	1180	1118	1060	1005	952	902	855	810	767	725	686	648	612	578	544	512
74	1502	1422	1347	1277	1211	1148	1089	1033	980	929	881	835	792	750	710	672	635	600	567	534
75	1536	1456	1380	1309	1241	1178	1118	1061	1008	956	908	861	817	775	734	695	658	623	589	556
76	1571	1489	1413	1340	1272	1208	1147	1089	1035	983	934	887	842	799	758	719	681	645	611	578
77	1606	1523	1445	1372	1303	1238	1177	1118	1063	1011	961	913	867	824	782	743	705	668	633	599
78	1641	1557	1478	1404	1334	1268	1206	1147	1091	1038	987	939	893	849	807	766	728	691	655	621
79	1676	1591	1511	1436	1365	1299	1235	1175	1119	1065	1014	965	918	873	831	790	751	713	678	643
80	1711	1625	1544	1468	1396	1329	1265	1204	1147	1092	1040	991	943	898	855	813	774	736	700	665
81	1746	1658	1577	1500	1427	1359	1294	1233	1175	1119	1067	1017	969	923	879	837	797	759	722	687
82	1781	1692	1610	1532	1458	1389	1323	1261	1203	1147	1093	1043	994	948	904	861	821	782	745	709
83	1816	1726	1643	1564	1489	1419	1353	1290	1231	1174	1120	1069	1020	973	928	885	844	805	767	731
84	1851	1760	1676	1596	1521	1450	1382	1319	1259	1201	1147	1095	1045	998	952	909	867	828	789	753
85	1886	1794	1709	1628	1552	1480	1412	1348	1287	1229	1173	1121	1071	1023	977	933	891	851	812	775
86	1921	1828	1742	1660	1583	1510	1442	1376	1315	1256	1200	1147	1096	1048	1001	957	914	874	834	797
87	1956	1863	1775	1692	1614	1541	1471	1405	1343	1284	1227	1173	1122	1073	1026	981	938	897	857	819
88	1992	1897	1808	1724	1645	1571	1501	1434	1371	1311	1254	1200	1147	1098	1050	1005	961	920	880	841
89	2027	1931	1841	1757	1677	1602	1531	1463	1400	1339	1281	1226	1173	1123	1075	1029	985	943	902	863
90	2062	1966	1875	1789	1708	1633	1561	1492	1428	1367	1308	1252	1199	1148	1100	1053	1009	966	925	886

Table of Gay-Lussac for procuring a weaker alcohol of a certain strength from a stronger.—*Continued.*

1000 vols. of alcohol of per cent. by vol.	Desired strength of the spirit.																								
	Per cent. by volume.																								
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
51	21																								
52	41	20																							
53	62	41	20																						
54	83	61	40	19																					
55	103	81	60	39	19																				
56	124	102	80	59	38	19																			
57	145	122	100	78	58	38	19																		
58	166	142	120	99	77	57	37	18																	
59	187	163	140	118	96	76	56	37	13																
60	208	183	160	137	116	95	74	55	36	18															
61	229	204	180	157	135	114	93	73	54	35	17														
62	250	225	200	177	155	133	112	92	72	53	35	17													
63	271	245	221	197	174	152	131	110	90	71	52	34	17												
64	292	266	241	217	194	171	150	128	109	89	70	52	34	17											
65	313	286	261	237	213	190	168	147	127	107	88	69	51	33	16										
66	334	307	281	256	233	209	187	166	145	125	105	86	68	50	33	16									
67	355	328	301	276	252	229	206	184	163	143	123	104	85	67	49	32	16								
68	376	348	322	296	272	248	225	203	181	160	140	121	102	84	66	49	32	16							
69	397	369	342	316	291	267	244	221	200	178	158	138	119	101	82	65	48	32	16						
70	418	390	362	336	311	286	263	240	218	196	176	156	136	117	99	81	64	47	31	15					
71	439	411	383	356	331	306	282	259	236	214	193	173	153	134	116	98	80	63	47	31	15				
72	460	431	403	376	350	325	301	277	255	232	211	191	171	151	132	114	97	79	63	46	30	15			
73	482	452	424	396	370	344	320	296	273	251	229	208	188	168	149	131	113	95	78	62	46	30	15		
74	503	473	444	416	390	364	339	315	291	269	247	226	205	185	166	147	129	111	94	77	61	45	30	15	
75	524	494	465	437	409	383	358	333	310	287	265	243	222	202	183	164	145	127	110	93	76	60	45	29	14
76	546	515	485	457	429	403	377	352	328	305	283	261	240	219	199	180	162	143	126	109	92	75	60	44	29
77	567	536	506	477	449	422	396	371	347	323	300	278	257	236	216	197	178	159	142	124	107	91	75	59	44
78	588	557	527	497	469	442	415	390	365	341	318	296	274	253	233	213	194	176	157	140	123	106	90	74	58
79	610	578	547	517	489	461	434	409	384	360	336	314	292	271	250	230	211	192	173	155	138	121	105	88	73
80	631	599	568	538	509	481	454	428	402	378	354	331	309	288	267	247	227	208	189	171	153	136	120	103	87
81	653	620	588	558	529	500	473	447	421	396	372	349	327	305	284	263	243	224	205	187	169	152	135	118	102
82	674	641	609	578	549	520	492	465	440	415	390	367	344	322	301	280	260	240	221	203	184	167	150	133	117
83	696	662	630	599	569	540	512	485	458	433	409	385	362	339	318	297	276	256	237	218	200	182	165	148	131
84	717	683	651	619	589	559	531	504	477	451	427	403	379	357	335	313	293	273	253	234	216	198	180	163	146
85	739	705	671	640	609	579	550	523	496	470	445	421	397	374	352	330	309	289	269	250	231	213	195	178	161
86	761	726	692	660	629	599	570	542	515	488	463	438	415	391	369	347	326	305	285	266	247	229	211	193	176
87	782	747	713	681	649	619	589	561	534	507	481	456	432	409	386	364	343	322	302	282	263	244	226	208	191
88	804	769	734	701	669	639	609	580	553	526	500	474	450	426	403	381	359	338	318	298	279	260	241	223	206
89	826	790	755	722	690	659	629	600	572	544	518	493	468	444	421	398	376	355	334	314	295	275	257	239	221
90	848	812	777	743	710	679	648	619	591	563	537	511	486	462	438	415	393	372	351	331	311	291	273	254	236

Table of Gay-Lussac for procuring a weaker alcohol of a certain strength from a stronger.—*Concluded.*

1000 vols. of alcohol of per cent. by vol.	Desired strength of the spirit.														
	Per cent. by volume.														
	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
76	14														
77	29	14													
78	43	28	14												
79	57	43	28	14											
80	72	57	42	28	14										
81	86	71	56	42	27	14									
82	101	85	70	56	41	27	13								
83	116	100	85	70	55	41	27	13							
84	130	114	99	84	69	55	40	27	13						
85	145	129	113	98	83	68	54	40	26	13					
86	159	143	127	112	97	82	68	54	40	26	13				
87	174	158	142	126	111	96	81	67	53	39	26	13			
88	189	172	156	140	125	110	95	81	66	53	39	26	13		
89	204	187	171	155	139	124	109	94	80	66	52	39	26	13	
90	219	202	185	169	153	138	123	108	94	79	66	52	39	26	13

The tables for determining the per centage of alcohol, as given in the preceding pages, cannot all be consulted when ascertaining the quantity of spirit in a liquid, and from this fact they might be looked upon as unnecessary; they serve, however, to give a clear view of the composition of alcoholic liquors of different states of dilution, and under the influence of various degrees of temperature and pressure, enabling the diligent student to draw up tables of great accuracy and of less extent, for reference on all ordinary occasions. This arrangement has been already effected, as in Sykes' and many other tables. From what has been said upon the properties of alcohol at the beginning of the subject, in relation to its real specific gravity, as determined by DRINKWATER, it will be observed that none of the enumerated tables are strictly correct, since the density of absolute alcohol—to which all the other densities bear a proportionate analogy—stated in them, is considerably higher than that assigned to it by the forementioned chemist.

Hence the necessity of constructing new tables, corresponding to the density of absolute alcohol, as found by recent experiments, becomes urgent.

The annexed is a contraction of the foregoing table of **GAY LUSSAC**, showing the dilution per cent. in reducing liquors to a lower strength. The upper horizontal column contains the per cent. of the stronger alcohol, and the vertical columns below, the bulk of water which is to be added to 100 volumes of it, to produce spirit of the quality indicated in the left-hand column.

Desired strength in per cent.	100 vols. of alcohol of per cent. by vol.								
	90	85	80	75	70	65	60	55	50
85	6·56								
80	13·79	6·83							
75	21·89	14·48	7·20						
70	31·05	23·14	15·35	7·64					
65	41·53	33·03	24·66	16·37	8·15				
60	53·65	44·48	35·44	26·47	17·58	8·76			
55	67·87	57·90	48·07	38·32	28·63	19·02	9·47		
50	84·71	73·90	63·04	52·43	41·73	31·25	20·47	10·35	
45	105·34	93·30	81·38	69·54	57·78	46·09	34·46	22·90	11·41
40	130·80	117·34	104·01	90·76	77·58	64·48	51·43	38·46	25·55
35	163·28	148·01	132·88	117·82	102·84	87·93	73·08	58·31	43·59
30	206·22	188·57	171·05	153·61	136·04	118·94	101·71	84·54	67·45
25	266·12	245·15	224·30	203·53	182·83	162·21	141·65	121·16	100·73
20	355·80	329·84	304·01	278·26	252·58	226·98	201·43	175·96	150·55
15	505·27	471·00	436·85	402·81	368·83	334·91	301·07	267·29	233·64
10	804·54	753·65	702·89	652·21	601·60	551·06	500·59	450·19	399·85

Adulterations of Spiritous Liquors and their detection.—The sophistication of alcoholic liquors has been practised to give to many solutions containing very little spirit, the appearance and some of the physical properties which would be conferred by alcohol; and adulterations have also been practised with a view, as it were, of veiling the quantity of spirit.

Such proceedings are invariably the result of dishonest trade; though, of the two evils, the former is the viler in its tendency. The counterfeiting of strong alcoholic liquors apparently as weaker spirit, or passing them off as quite a different liquid, was fostered in the wine-growing countries of the continent, where large quantities of brandy were manufactured; and before the proper means of detection were at command, the strongest brandy was often sold to the merchants disguised as ordinary wine, or a much weaker spirit, and by this means the *Octroi* duties were eluded. The imposition had long been practised after the introduction of various hydrometric or alcoholometric scales for the determination of the amount of alcohol in spiritous liquors; for, as most of these were on the principle of the gravity test, advantage was taken by adding various substances which would heighten the density, and make it appear that the spirit was much more aqueous than it really was. In other instances the spirit was passed upon the Excise as quite a different article, sometimes as a deodorising agent, while at other times it was made to assume the character of wood naphtha. Expedients such as these have been countenanced in this country; and in the large towns where much alcoholic liquor is consumed, the contrary vice of vending drinks to the public which are said to be alcoholic, but in reality contain little or no spirit, is frequently practised among some of the liqueur fabricators, who add supervacaneous substances, making an *olla podrida*. To defraud the Excise, sugar, or other extractive matter, is added to the spirit, to increase the specific gravity, and sometimes wood-spirit, turpentine, pyroligneous acid, chlorine water, or other bodies possessing a strong odor, are added to the liquor, and in this case it is represented as not being alcoholic.

The detection of these frauds is, for the most part, easy and expeditious. In case sugar, extractive matter, pyroligneous acid, turpentine, *et cetera*, are suspected, it is only necessary to distil a portion of the liquid, and determine the density of the distillate by the hydrometer, or specific gravity bottle, and on referring to the corresponding gravity in either of the tables already given, under *alcoholometry*, the corresponding value of alcohol is found. When a liquor is disguised as wood naphtha, it is more difficult to determine the amount of alcohol; distillation, as in the forementioned instance, is ineffectual, for the naphtha passes over at even a lower degree of heat than the alcohol. The following is the method recommended by Dr. **URE** for the detection of alcohol in wood or coal naphtha, or pyroligneous acid:—

A small quantity of nitric acid of specific gravity 1·45, is first to be added to the spirit under examination, and if alcohol be present, it will immediately produce an effervescence of nitrous ether gas, which may be recognized as such by its odor. The mixture is then treated with a solution of mercury in nitric acid—which is prepared by dissolving one hundred grains of mercury in one fluid ounce of this acid, with the help of heat. Soon after this addition, and especially on raising the temperature, the mixture begins to effervesce and to evolve thick ethereal vapors; should the effervescence become too violent, it must be quelled by immediately withdrawing the fire, and cooling the vessel. A yellowish grey precipitate falls down, which is fulminate of mercury, and which should be immediately separated by decanting or filtering the liquor from it, washing the precipitate on the filter with a little distilled water, and carefully drying it at a heat which must not exceed 100° Fahr.; after which it is weighed. The quantity of fulminate of mercury obtained is nearly equal to that of the alcohol contained in the wood-spirit; and at any rate, the formation of the detonating salt is quite characteristic of the presence of alcohol, since wood-spirit treated by nitric acid in the presence of mercury or silver, produces neither fulminate of silver nor fulminate of mercury.

In applying this test, the greatest care should be exercised, and every precaution taken to prevent contact of any hard body with the precipitate, since the fulminates of silver and mercury, and especially the former, are so very explosive; the fulminate of silver has been known to explode by contact with a glass rod, even under water; the fulminate of mercury is less explosive, and on that account is preferred. For the purpose of collecting these compounds, the feather of a quill should be used; and if the quantity is at all considerable, that is, if it exceeds a few grains, it should be collected in several filters so as to handle only small portions at a time. During the evolution of the ethereal vapors before alluded to, all approach of flame should be carefully avoided.

The same chemist gives the following as the principal tests whereby to discern alcohol from wood naphtha, and also whether the latter is genuine or mixed with alcohol:—

1st. The boiling point of pure wood naphtha spirit is at least 20° Fahr. below that of alcohol of the same density, and it exhales the characteristic, pungent, and offensive odor of aldehyde. In the course of his experiments he found the boiling point of—

Wood-spirit, of specific gravity, ·870, to be	144° Fahr.
Alcohol, of like gravity, ...	180° „
Wood-spirit, of specific gravity, ·832, ...	140° „
Alcohol, of the same density, ...	171·1° „

If ten per cent. of naphtha be mixed with alcohol, the boiling point is lowered at least 6° Fahr.

2nd. When rectified naphtha is distilled at the temperature of boiling water from a large quantity of lime, the distillate is unchanged in its gravity, whilst if alcohol, or a mixture of alcohol and naphtha, be subjected to the same treatment, the first portions that come over are nearly absolute, and stand at a density below ·800, and contain, at 60° Fahr., about seventy per cent. over proof. The reason of this characteristic difference seems to be that naphtha possesses a stronger affinity for water than alcohol.

3rd. When water is added to alcohol, the specific gravity of the liquor becomes reduced in a less proportion than when wood-spirit of the same gravity as the alcohol is diluted with the same quantity of water. Thus, for example, if alcohol of a given density is diluted with a certain quantity of water, so as to bring it to specific gravity 0·920, wood-spirit of the same original gravity, and diluted with the same quantity of water, will become of specific gravity 0·926 or 0·927.

Dr. Ure says that caustic potassa in powder is the most delicate test for the detection of wood-spirit in alcohol; for if wood-spirit is present the liquor assumes then a brown color, whilst pulverized potassa does not alter the color of pure alcohol, even after several hours, and it is only after a whole day's contact that a feeble yellowish tinge is then developed. But if the alcohol contains only two per cent., or even one per cent. of wood-spirit, it turns yellowish in the course of ten minutes, and brown in half an hour.

On the other hand, where brandies, gins, and other alcoholic liquors are artificially made by admixture of various ingredients with alcohol, as is directed under these heads, it is not uncommon to find that the alcohol, in such compounded articles, is attenuated as low as possible, and that the agreeableness of taste, and the pungency of flavor peculiar to the genuine beverages, are conferred by means of pepper, cayenne, or other acrid substances. These sophistications are discovered by evaporating a known quantity of the liquid to dryness at a gentle heat; the impure matters remain, and may be recognised by their flavor.

Various alcoholometers have been lately constructed for the purpose of ascertaining the content of alcohol, irrespective of the density. The first instrument of this description was constructed, as already stated, by M. Brossard-Vidal, and was improved by Conaty. Ure's modification of this instrument, which is given at page 136, determines the amount of alcohol from the boiling point; and more recently, Silbermann, to obviate the discrepancies attendant upon other methods, constructed his dilatometer, which has been likewise described. These instruments determine the amount of alcohol, without referring to the foreign bodies which may have been present in the liquor.

Acetates of copper and lead are rarely detected in brandies, owing to the repeated distillations to which the spirit is subjected, but where the old stills are employed, the solder connecting the seams of the still is dissolved by the small quantity of acetic acid present in the liquors; it has likewise been known that acetate of lead—sugar of lead—has been added to facilitate the clarifying process. Liquors thus treated may prove extremely pernicious, since acetate of lead is highly poisonous. By filtering the brandy through animal charcoal, and adding sulphuric acid to the clear liquor, if the lead has been present in excess, a white precipitate appears; if there is no precipitate, a stream of sulphide of hydrogen is to be transmitted through the liquid, and if any lead is present, a black precipitate, or coloration is produced. Should a white precipitate be obtained by the action of sulphuric acid, or sulphate of soda, on the brandy, it is turned black by the addition of sulphide of ammonium, and if the precipitate should be bulky it may be mixed with a little carbonate of soda, and reduced on charcoal before the blowpipe to a globule of metal.

Copper may be detected by filtering a portion of the brandy through animal charcoal, to decolorize it; ammonia is then to be added to the clear liquor, to which it will impart a blue tinge, if copper be present, at least in sufficient quantity. Several hours are sometimes requisite to determine this appearance. The presence of copper may also be detected by immersing a blade of perfectly clean iron in the brandy, and leaving it there for a few hours, when it will be found coated with a film of metallic copper. The brandy, first decolorized by animal charcoal, may also be tested for copper by a solution of ferrocyanide of potassium, which will produce a reddish brown precipitate with this metal.

STATISTICS OF THE SPIRIT TRADE OF GREAT BRITAIN AND IRELAND, FROM THE PARLIAMENTARY REPORTS OF THE INLAND REVENUE.—Without recurring to the period when the English distiller had to pay a duty of eleven shillings and eightpence farthing on every gallon of spirits distilled, or to the time that the Scotch distiller had to contend with a revenue rental of one hundred and sixty-two pounds sterling upon every gallon capacity of his still, it may be interesting to give a brief statement of the extent of the spirit trade, and the amount of revenue which through this channel flows into the Exchequer. Every English distiller has now to pay a licence duty of ten guineas before he can lawfully conduct operations, and afterwards a duty of eight shillings per imperial gallon of spirits, proof strength, which he produces.

The Scotch and Irish distillers have to pay the same licence fee as the English, and in addition to this the Scotch distiller, like the English, pays a duty of eight shillings per imperial gallon of proof strength, being an increase of four shillings and fourpence per gallon above what was paid by the Scotch distiller previous to the 1st of April, 1853; the Irish manufacturer also pays a duty of six shillings and twopence per gallon, proof strength. Regarding the spirit imported from Guernsey, Jersey, Alderney, and Sark, into England, Scotland, and Ireland, the Government enjoins that a countervailing duty of nine shillings be paid upon every gallon of proof strength, and of the quality of plain British spirit, that enters England or Scotland; and of seven shillings and twopence per proof gallon upon what is brought into Ireland.

By an Act passed in 1855, the duties on spirits in England and Scotland are equalized; and the countervailing duty on spirit imported from Ireland into England or Scotland was regulated as follows:—

Articles enumerated. For every gallon thereof removed.	Countervailing Duties from Ireland to England or Scotland. £	s.	d.
Ether,	0	4	7
Sweet spirit of nitre,	0	2	9
Camphorated spirit,			
Lavender water, and other perfumes, being spirits scented with essential oils, flowers, and other ingredients,			
Compound spirit of lavender,			
Spirit of rosemary,			
Spirit of ammonia,			
Sal volatile,			
Friars' balsam,			
Compound tincture of benzoin,			
Tinctures of asafœtida, castor, kino, guaiacum, myrrh, and ginger,			
Spirit varnishes,			
Other tinctures and medicated spirits,	0	1	10
Made wines,	0	0	2¾

An important feature in the Act of 1853 was the redress of a grievance under which the distiller labored, from being required to pay the full amount of duty on bonded spirit, without any allowance being made for the waste by evaporation. When liquors remained for a long time in store, this loss amounted to something considerable, and for which the owner had to pay the same duty as for the original quantity of spirit. A drawback of a quarter of a gallon is now allowed for every hundred gallons of spirit remaining in bond for seven days; and for longer periods, as follows:—

For a period over 7 days,	and under 14 days,	½ a gallon.
14 "	" 1 month,	¾ "
1 month,	" 2 "	1 "
2 "	" 3 "	1¼ "
3 "	" 6 "	1¾ "
6 "	" 9 "	2¼ "
9 "	" 12 "	2¾ "

Above this time an additional allowance of three-fourths of a gallon is made for every six months, or multiple thereof up to five years, during which the above quantity of spirit may be warehoused.

The number of distillers and rectifiers in the United Kingdom, during the series of years, from 1846 to 1854, both inclusive, is shown in the following table:—

Year ending 5th Jan.	England.	Scotland.	Ireland.	Total.
1846	94	174	100	377
1847	93	176	93	367
1848	90	169	96	355
1849	85	168	89	342
1850	86	164	87	337
1851	86	166	88	340
1852	85	159	80	324
1853	88	149	72	309
1854	89	145	71	305

The licence duty for these distilleries during the same period, in—

	England.	Scotland.	Ireland.	Total.
1846,	£987 0 0	£1921 10 0	£1050 0 0	£3958 10 0
1847,	976 10 0	1900 10 0	976 10 0	3853 10 0
1848,	945 0 0	1837 10 0	1008 0 0	3790 10 0
1849,	892 10 0	1827 0 0	934 10 0	3654 0 0
1850,	903 0 0	1753 10 0	913 10 0	3570 0 0
1851,	903 0 0	1743 0 0	924 0 0	3570 0 0
1852,	892 10 0	1669 10 0	840 0 0	3402 0 0
1853,	924 0 0	1564 10 0	756 0 0	3244 10 0
1854,	934 10 0	1522 10 0	745 10 0	3202 10 0

The revenue arising from home-made spirits in the preceding years:—

	England.	Scotland.	Ireland.	Total.
1846,	£3,595,315	£1,278,766	£1,060,276	£5,934,359
1847,	3,293,589	1,135,428	804,984	5,234,003
1848,	3,373,525	1,200,501	943,057	5,517,084
1849,	3,546,023	1,271,417	929,777	5,747,218
1850,	3,654,842	1,305,880	987,744	5,948,467
1851,	3,758,185	1,252,296	1,006,735	6,017,218
1852,	3,846,404	1,314,869	1,094,434	6,255,708
1853,	4,053,870	1,433,400	1,273,151	6,760,421
1854,	4,265,097	1,806,934	1,588,745	7,660,776

In comparing the indications of the preceding three tables, it will be observed from the first that the total number of distillers and rectifiers in the United Kingdom, which, in 1846, amounted to three hundred and seventy-seven, was only three hundred and five in 1854, exhibiting therefore a decrease of seventy-three —equivalent to nineteen per cent.—during nine years. In Ireland, the decrease was twenty-nine per cent., in Scotland sixteen per cent., and in England only five per cent. At the same time it appears from the last table, that while the number of the rectifiers and distillers was diminishing to that amount, the total revenue derived from home-made spirits during the same period was steadily increasing, showing that while the establishments were being reduced in number, they were greatly extending in magnitude.

Exclusive of rectifiers, the number of distillers licensed in 1855–56, in the three kingdoms, was as follows:—England, 11; Scotland, 134; Ireland, 39.

The following table exhibits a return of the quantity of spirit distilled, and the quantity charged with duty for home consumption in the United Kingdom, from 1800 to 1854, both inclusive, distinguishing the quantities so distilled and consumed in England, Scotland, and Ireland respectively:—

Years.	Number of imperial gallons of spirit distilled in				Number of imperial gallons of spirit charged with duty for consumption in			
	England.	Scotland.	Ireland.	United Kingdom.	England.	Scotland.	Ireland.	United Kingdom.
1800	4,352,788	1,277,696	There are no records from which an account for this period can be furnished.		4,352,888	1,277,596	1,330,500	6,960,984
1801	2,478,289	295,931			2,555,920	295,931	355,106	3,206,957
1802	3,384,742	1,344,835	4,475,458	9,205,035	3,981,072	1,158,558	4,715,098	9,854,728
1803	4,184,034	2,247,000	4,795,109	11,226,143	5,370,377	2,022,409	4,343,095	11,735,881
1804	2,586,586	2,478,003	4,205,830	9,270,419	3,690,745	1,889,757	3,543,599	9,124,101
1805	2,869,520	2,617,508	4,611,734	10,098,762	4,932,645	1,625,987	3,686,233	10,244,865
1806	2,425,007	2,788,274	4,059,914	9,273,195	4,094,985	1,812,237	3,858,107	9,765,329
1807	3,581,043	3,397,204	5,305,632	12,283,879	4,747,365	2,653,478	5,597,204	12,998,047
1808	3,847,127	3,589,435	4,524,475	11,961,037	5,390,884	2,683,342	3,575,430	11,649,656
1809	3,307,039	2,610,512	1,288,758	7,206,309	4,035,825	1,315,135	1,360,386	6,711,346
1810	3,898,966	2,171,513	4,301,026	10,371,505	4,787,555	1,748,140	4,728,522	11,264,217
1811	4,116,833	2,859,861	6,187,779	13,164,473	4,776,330	1,951,092	6,378,479	13,105,901
1812	3,938,793	3,001,677	4,053,600	10,994,070	5,242,470	1,687,905	4,009,301	10,939,676
1813	3,859,095	1,842,817	3,595,030	9,296,942	4,292,477	1,234,291	3,158,693	8,685,461
1814	3,670,714	2,988,323	5,947,658	12,606,695	4,959,965	1,474,187	5,393,713	11,824,865
1815	3,402,489	3,024,430	4,468,106	10,895,025	5,468,987	1,591,148	4,323,844	11,383,979
1816	3,486,478	2,145,366	4,562,286	10,194,130	4,745,484	918,859	3,557,200	9,221,543
1817	2,907,732	3,060,499	2,692,182	8,660,413	4,133,063	1,906,950	3,586,932	9,626,945
1818	3,782,512	3,062,820	4,474,777	11,320,109	5,259,662	2,066,988	4,284,347	11,610,997
1819	2,815,716	3,547,199	3,879,216	10,242,131	4,146,505	2,125,150	3,676,516	9,948,171
1820	2,866,684	3,278,129	4,607,296	10,752,109	4,284,798	1,863,987	3,299,650	9,448,435
1821	2,662,852	3,216,858	3,627,552	9,507,262	4,125,616	2,385,495	3,311,462	9,822,573
1822	3,181,026	3,337,850	4,135,045	10,653,921	4,694,055	2,225,124	2,910,483	9,829,662
1823	2,134,913	3,083,515	2,844,677	8,063,105	3,803,312	2,303,286	3,590,376	9,696,974
1824	2,894,309	5,908,373	6,361,248	15,163,930	4,392,611	4,350,301	6,690,315	15,433,227
1825	2,039,771	8,224,807	8,835,027	19,099,605	3,684,049	5,981,549	9,262,744	18,928,342
1826	3,209,044	8,563,994	9,046,959	20,819,997	7,407,204	3,988,788	6,834,867	18,230,859
1827	3,451,620	7,243,819	7,283,317	17,978,756	6,671,562	4,752,199	8,260,664	19,684,425
1828	3,974,785	10,117,047	9,725,259	23,817,091	7,759,687	5,716,180	9,937,903	23,413,770
1829	3,860,542	9,649,070	9,208,538	22,718,150	7,700,766	5,777,280	9,212,224	22,690,270
1830	4,656,443	9,883,413	8,694,742	23,234,598	7,732,101	6,007,631	9,004,539	22,744,271
1831	3,444,792	9,510,268	8,786,341	21,741,401	7,434,047	5,700,689	8,710,672	21,845,408
1832	3,788,068	7,979,088	9,260,920	21,028,076	7,281,900	5,407,097	8,657,756	21,346,753
1833	4,591,223	9,146,889	9,509,774	23,247,886	7,717,303	5,988,556	8,168,596	21,874,455
1834	4,652,838	9,193,091	9,370,343	23,216,272	7,644,301	6,045,043	9,708,416	23,397,760
1835	4,327,425	9,133,449	11,167,580	24,628,454	7,315,053	6,013,932	11,381,223	24,710,208
1836	5,088,340	10,222,650	11,894,169	27,205,159	7,875,702	6,620,826	12,248,772	26,745,300
1837	4,614,196	9,012,485	10,980,910	24,607,591	7,133,869	6,124,035	11,235,635	24,493,539
1838	5,776,411	9,047,199	11,064,820	25,888,430	7,930,490	6,259,711	12,296,342	26,486,543
1839	5,685,698	9,871,653	10,254,591	25,811,942	8,186,552	6,188,582	10,815,709	25,190,843
1840	5,918,435	8,821,530	7,281,429	22,021,394	8,278,148	6,180,138	7,401,051	21,859,337
1841	5,919,207	8,504,333	6,359,124	20,782,664	8,166,985	5,989,905	6,485,443	20,642,333
1842	6,008,456	7,658,985	5,315,090	18,982,531	7,956,054	5,595,186	5,290,650	18,841,890
1843	5,800,509	7,650,272	5,550,706	19,001,487	7,724,051	5,593,798	5,546,483	18,864,332
1844	5,433,843	8,321,306	6,878,243	20,633,392	8,234,440	5,922,948	6,451,137	20,608,525
1845	5,866,593	9,418,663	8,397,459	23,682,715	9,076,381	6,441,011	7,605,196	23,122,588
1846	5,624,868	9,735,303	8,658,879	24,019,050	9,179,530	6,975,091	7,952,076	24,106,697
1847	5,356,794	8,542,219	5,737,687	19,636,700	8,409,165	6,193,249	6,037,383	20,639,797
1848	5,503,238	9,600,321	8,126,507	23,230,066	8,581,327	6,548,190	7,072,933	22,202,450
1849	5,573,411	10,846,634	8,355,083	24,775,128	9,053,676	6,935,003	6,973,333	22,962,012
1850	5,913,424	11,638,429	8,293,034	25,844,887	9,331,512	7,122,987	7,408,086	23,862,585
1851	6,127,181	10,380,972	8,035,504	24,543,657	9,595,368	6,830,710	7,550,518	23,976,596
1852	6,363,276	9,942,218	8,117,708	24,423,202	9,820,608	7,172,015	8,208,256	25,200,879
1853	7,308,670	10,359,926	8,772,961	26,441,557	10,350,307	6,534,648	8,136,362	25,001,317
1854	6,831,664	9,862,318	8,259,930	25,003,912	10,889,611	6,553,239	8,440,734	25,883,584

It will be observed by consulting the foregoing table, based upon parliamentary returns, that the spirit distilled in England in the early part of this century, was equal to that of Ireland, and greater than the total produce of Scotland. Coming down to later years, however, a very remarkable difference is apparent between the quantities afforded by the three nations, particularly as regards Scotland and England, for in 1850 there was nearly double the number of gallons distilled in the former, as in the latter country. It is obvious that this apparent anomaly is to be attributed to the fact, that in Scotland and Ireland the revenue returns embraced but a small proportion of the spirit actually distilled in 1800, and few succeeding years, as the business was at that time chiefly conducted by smugglers or illicit distillers.

Selecting, as an average example, the year 1852, the following are the relative proportions of spirit extracted from the different ingredients used:—

	England. gallons.	Scotland. gallons.	Ireland. gallons.
From malt only,.........	—	....5,276,266....	10,056
From a mixture of malt with unmalted grain,	5,155,069....	2,363,259....	7,841,915
From a mixture of sugar and molasses with unmalted grain,.......	1,208,207....	2,295,901....	265,737
From molasses,..........	—	6,792....	—
	6,363,276	9,942,218	8,117,708

Spirit made in Scotland from malt only is entitled to an abatement of sevenpence-halfpenny per gallon, and 5 per cent. when exported, used as ship stores, or when removed to a warehouse in England or Ireland. A like drawback is allowed to distillers in England and Ireland, provided they work under the same regulations as Scotch distillers, and when they warehouse specifically for exportation, or for ships' stores.

To complete the statistics of the spirit trade, it only remains to annex a return of the quantity of foreign and colonial spirits of all sorts entered for home consumption in the United Kingdom, in each year, from 1800 to 1854, both inclusive; distinguishing, in this case also, the quantities consumed in England, Scotland, and Ireland respectively.

Years.	Number of imperial gallons, including over-proof, of foreign and colonial spirits entered for home consumption in			
	England.	Scotland.	Ireland.	United Kingdom.
1800	3,641,684	354,010	1,034,823	5,030,517
1801	3,595,063	634,559	1,364,261	5,593,883
1802	4,187,687	824,320	729,635	5,741,642
1803	4,677,921	577,703	296,259	5,551,883
1804	2,817,014	155,296	202,879	3,175,189
1805	3,283,811	225,376	148,724	3,657,911
1806	3,789,704	289,589	183,483	4,262,776
1807	3,704,665	355,354	228,589	4,288,608
1808	4,357,886	355,025	378,359	5,091,270
1809	3,200,917	325,876	1,132,816	4,659,609
1810	4,421,249	401,408	358,741	5,181,398
1811	3,766,977	353,163	154,547	4,274,687
1812	3,380,996	298,451	291,415	3,970,862
1813	3,278,766	246,808	474,489	4,000,063
1814	3,948,581	313,994	104,392	4,366,967
1815	3,759,409	322,606	74,439	4,156,454
1816	2,950,113	218,329	28,123	3,196,565
1817	2,883,443	233,682	36,734	3,153,859
1818	3,017,535	237,519	30,630	3,285,684
1819	3,242,207	186,886	35,939	3,465,032
1820	3,241,898	174,764	29,798	3,446,460
1821	3,135,915	172,790	29,010	3,337,715
1822	3,155,465	166,618	25,260	3,347,343
1823	3,354,022	142,859	43,457	3,540,338
1824	3,675,816	182,696	10,805	3,869,317
1825	3,329,289	161,306	14,678	3,505,273
1826	5,480,283	337,597	37,210	5,855,090
1827	4,401,373	227,970	32,419	4,661,762
1828	4,390,007	233,838	34,487	4,658,332
1829	4,477,214	195,689	31,636	4,704,539
1830	4,770,541	175,486	29,701	4,975,728
1831	4,697,882	165,446	29,467	4,892,795
1832	4,932,337	181,262	57,845	5,171,444
1833	4,664,785	171,053	44,150	4,879,988
1834	4,554,086	155,917	55,346	4,765,349
1835	4,571,580	146,178	47,948	4,765,706
1836	4,425,543	146,785	44,692	4,617,020
1837	4,264,146	120,940	39,379	4,424,465
1838	4,205,742	124,544	37,939	4,368,225
1839	3,877,374	115,243	32,800	4,025,417
1840	3,526,199	91,358	26,853	3,644,410
1841	3,344,922	88,814	30,338	3,464,074
1842	3,099,542	71,927	29,546	3,201,015
1843	3,061,699	71,820	28,438	3,161,957
1844	3,134,350	78,142	30,114	3,242,606
1845	3,431,614	84,478	33,797	3,549,889
1846	4,087,608	114,678	43,044	4,245,330
1847	4,237,406	455,441	210,206	4,903,053
1848	4,103,156	322,543	209,664	4,635,363
1849	4,644,811	368,638	255,476	5,268,925
1850	4,302,513	289,200	213,463	4,805,176
1851	4,320,946	260,184	202,498	4,783,628
1852	4,389,414	265,447	211,397	4,866,258
1853	4,670,051	260,880	211,685	5,142,616
1854	4,699,862	255,580	172,701	5,128,143

It will be observed that there is little variation in the total amount for the three kingdoms, but that the quantities consumed in Scotland, and more especially in Ireland, have been subject to great fluctuations.

It is calculated that, in addition to 24,000,000 gallons of home-made spirit annually consumed in the United Kingdom, there are 4,000,000 gallons of brandy, rum, and geneva. In the year ending January 5, 1853, the quantity of British spirit exported was 323,719 gallons, of which 161,532 were sent to British colonies and possessions, and 162,187 gallons to foreign countries. Of the British possessions, the smallest customer was the island of Mauritius, which only took 5 gallons. The largest quantity was taken by the Australian settlements, *videlicet*, 125,667 gallons. Of foreign countries, Russia, Sweden, Denmark, Prussia, Holland, Belgium, France, Portugal, and Morocco, took each less than 100 gallons. The foreign West Indies are the best customers, taking 156,360 gallons. It is very probable that Australia will soon become the best market for home-made spirit.

In conclusion, the Editor must express his satisfaction at the equalization of the duties on spirits, as regards England and Scotland—a step which was not only wise in itself, as tending to assimilate still further the condition of the two countries, but likewise by removing an inducement to the practice of smuggling, which, although sometimes regarded with leniency, is most demoralizing in its tendency, and ought to be universally reprobated.

ALUM.—*Alun*, French; *Alaun*, German; *Alumen*, Latin. Alum-works existed many centuries ago at Roha, or Roccha, in Mesopotamia, whence the old name of Roch alum is applied to this salt. This is the opinion of LEIBNITZ, who states that *alumen roccæ* was that kind first procured from Rocca, and that the name was subsequently given to every good species of alum. A few are of opinion that alum obtained from alum-stone has been so called to distinguish it from the alum from schists—schist was employed for making alum in the time of AGRICOLA—which usually contains more iron than the former; and others assert that alum acquired the name *rocca*, from the aluminous rocks of Tolfa.

At a later date, alum was manufactured near Smyrna, and in the fifteenth century there were alum factories in the vicinity of Constantinople, where JOHN DI CASTRO learned his art, as will be hereafter noticed.

The inhabitants of Genoa, and other commercial people of Italy, imported alum from the above places into Western Europe for the use of the dyers of red cloth. The stypteria of DIOSCORIDES and the alumen of PLINY included, apparently, a variety of saline matters, of which sulphate of iron—green vitriol—as well as alumina, was probably a constituent part. From the researches of Professor BECKMANN, it appears that alum was discovered by the Asiatics; but at what period, or by what means the discovery was made, is altogether unknown. This salt affords a striking instance of how readily one may be deceived in giving names without proper examination. Alum, as now made, adds BECKMANN, was certainly not known to the Greeks or the Romans; and what the latter called *alumen*, was green vitriol—sulphate of iron—not, however, pure, but such as forms in mines. To those who know how deficient the ancients were in the knowledge of salts, and of mineralogy in general, this assertion will appear highly probable. PEREIRA remarks that GEBER, who is supposed to have lived in the eighth century, was conversant with alum, and described the method of burning it; and it is probable that even PLINY was acquainted with it. It would seem, however, that he confounded alum with sulphate of iron, or a very impure compound, for, when speaking of some substance resembling plumose alum, he says it gave with the juice of the pomegranate a black color, at once a proof that the sulphate of iron was not separated from it. Alum and green vitriol are salts having some resemblance; they contain the same acid—sulphuric—have strong styptic properties; and are not only found collaterally, but frequently form efflorescences on the same minerals.

By alum is universally understood a double sulphate of alumina and potassa, which was the first known and used in the arts; modern science has discovered, however, that this compound does not exclusively engross the term, but that the latter is equally applicable to a series of bodies in which either the sesquisulphate of alumina, or sulphate of potassa, or both, are replaced by other sulphates of similar atomic composition. Notwithstanding that the whole mineral portion of the double salt is changed, yet every one of the class assumes the same crystalline form, and is associated with the same number of atoms of crystalline water. To this peculiarity of different bodies assuming the same external appearance when their atomic constitution is analogous, the term *isomorphism* has been applied. These alums are—

Name.	Formula.
Potassa alum,	$K O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Soda alum,	$Na O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Lithia alum,	$Li O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Ammonia alum,	$N H_4 O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Manganous-magnesia alum,	$\left.\begin{matrix}Mn O\\ Mg O\end{matrix}\right\} H O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Ferrous alum,	$Fe O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Ferric-potassa alum,	$K O, S O_3 + Fe_2 O_3, 3 S O_3 + 24$ aq.
Ferric-ammonia alum,	$N H_4 O, S O_3 + Fe_2 O_3, 3 S O_3 + 24$ aq.
Manganic alum,	$K O, S O_3 + Mn_2 O_3, 3 S O_3 + 24$ aq.
Chromic alum,	$K O, S O_3 + Cr_2 O_3, 3 S O_3 + 24$ aq.

It thus appears that the term alum is applied scientifically and collectively to a great number of double salts, composed of very different proximate elements, arranged, however, in the same manner; that alums are sometimes formed, in which the acid is sulphuric—$S O_3$; in other varieties chromic—$Cr O_3$; some containing potassa—$K O$; others soda—$Na O$, and others again oxide of ammonium—$N H_4 O$; and as the second base, either sesquioxide of iron—$Fe_2 O_3$, sesquioxide of aluminum—$Al_2 O_3$, or sesquioxide of chromium—$Cr_2 O_3$. These different bases and acids possess the power of replacing each other in variable proportions, or several of them may take part in the formation of one and the same crystal of alum, but in every case the alum will contain twenty-four equivalents of water.

Mangano-magnesian alum, and ferrous alum, are not of the regular crystalline form of the others, and, therefore, are not to be viewed as true alums, though their analogous composition to the other alums is the reason why they have been classed here. The name alum is applied, conformably with the preceding feature of the class, to all compound salts whose formula is $R O, S O_3 + R_2 O_3 3 S O_3 + 24$ aq., the letter R being indicative of any metal.

Alum, like saltpetre and carbonate of soda, occurs native, as an effloresced salt in volcanic districts, in the form of a white floccular covering, produced by the action of sulphuric acid vapors upon lava and trachyte —substances containing alumina and potassa—in a similar manner to that by which artificial alum is obtained. In this form it occurs in Auvergne, in the South of France, in Sicily, and the volcanic islands on its Northern coast, but more particularly in the neighborhood of Naples, in the Grotta di Alume—on Capo Miseno—and in the Solfatara.

The effloresced salt is collected in these localities, dissolved in water, and allowed to deposit the insoluble matters by standing. The clear solution affords on evaporation an impure alum, which is re-crystallized, and brought into commerce as a very pure product. No fuel is used for the evaporation but the natural volcanic heat of the soil, rising to 104° Fahr., in which the leaden pans are embedded. Native alum forms, however, a very small portion of that which is consumed in Europe. Dr. DIEFFENBACH, in his account of a voyage to New Zealand, makes mention of a remarkable lake, the water of which contained alum in solution.

The following is the composition of some of these natural alums:—

Constituents.	From Rio Saldanha, Andes.	Soda alum from South America.		Ammonia alum from Tschermig.		
	Thomson.	Thomson.	Gruner.	Pfaff.	Lampadius.	Stromeyer.
Sulphuric acid,	35·872	37·7	33·682	36·00	38·58	36·065
Alumina,	14·645	12·4	10·750	12·14	12·34	11·602
Soda,	2·262	7·5	—	—	—	—
Silica,	0·100	—	—	—	—	—
Lime,	—	—	—	—	—	—
Protoxide of iron,	—	—	3·619	—	—	—
Sesquioxide of iron,	0·500	—	—	0·20	—	0·115
Ammonia,	—	—	—	6·58	4·12	3·721
Water,	46·375	42·4	51·000	45·00	44·96	48·390
	99·754	100·0	99·051	99·92	100·00	99·893

MANGANESE AND MAGNESIA ALUMS.

Constituents.	Algoa Bay, South Africa.	Bosjesman's River, South Africa.	Iquique, South America.
	Apjohn.	Stromeyer.	Hayes.
Sulphuric acid,	32·79	36·770	36·332
Alumina,	10·65	11·515	12·130
Magnesia,	—	3·690	4·682
Protoxide of manganese,	7·33	2·617	0·430
Protoxide of iron,	—	—	
Lime,	—	—	0·126
Sulphate of magnesia,	1·08	—	—
Chloride of potassium,	—	0·205	—
Hydrochloric acid,	—	—	0·604
Water,	48·15	45·739	45·450
	100·00	100·536	99·754

Drs. RICHARDSON and RONALDS consider the alums analysed by APJOHN and STROMEYER, identical; they cannot be looked upon as chemical compounds, as no two analyses agree, and *in situ* they are much mixed with efflorescent salts. The manganese alum is used by the natives for dressing skins.

In the following table is a number of analyses of various specimens of iron alum—ferrous alum of the formula $FeO\,SO_3,\,Al_2\,O_3\,3\,SO_3 + 24$ aq. above mentioned—found in different localities. These kinds of natural alums are more abundant in coal mines, where iron pyrites and shale are superposed on the coals, and are often very regularly and beautifully crystallized. They are not, indeed, sufficiently pure to agree exactly with the foregoing formula, some of them containing potash, soda, magnesia, sand, or one or more of these substances, but still it will be seen from the table that their characteristic composition is nearly expressed by it:—

IRON ALUMS.

Constituents.	Unknown.	Hurlet.	Morsfeld.	Iceland.	Puzzuoli.		Hurlet.
	Berthier.	Phillips.	Rammelsberg.	Forchhammer.	Dufuroy.	Alich.	
Sulphuric acid,	34·4	30·9	36·025	35·16	45·67	48·32	35·950
Protoxide of iron,	12·0	20·7	9·367	4·57	28·69	11·60	—
Sesquioxide of iron,	—	—	—	1·23	—	17·65	18·236
Alumina,	8·8	5·2	10·914	11·22	3·27	2·20	—
Potash,	—	—	0·434	—	5·47	4·04	Ammonia, 3·653
Soda,	—	—	—	—	—	0·25	—
Magnesia,	0·8	—	0·235	2·19	—	—	
Sand,	—	—	—	—	0·46	—	Impurities, 3·500
Water,	44·0	43·2	43·025	45·63	15·77	15·94	38·661
	100·0	100·0	100·000	100·00	99·33	100·00	100·000

From what has already been stated, it will be seen that alums, of whatever elements they may be composed, are not merely a combination of sulphuric acid and alumina—$Al_2\,O_3\,3\,S\,O_3$—but have in addition another sulphate, either of potassa, soda, or ammonia. The alum of this country usually contains potassa; that of France, ammonia, or potassa and ammonia—hence the name potassa-alum, ammonia-alum, soda-alum. The Greeks or Romans mention no other than natural alum; but alum is rarely produced spontaneously in the earth, and many most accurate mineralogists deny even the existence of native alum. Although it is not found in abundance, still there can be no question as to its occasional occurrence as an efflorescence of stones, and in certain mineral waters. Crystals of real alum are occasionally formed in minerals abounding in an eminent degree with aluminous particles, when they have been exposed a sufficient time to the air and rain; but even then they are so small, and so much scattered, that it requires a good lens and an expert observer to discover them. Basic alum exists native in a stone near Civita Vecchia, which consists of—

Sulphate of potassa,	19·72
Sulphate of alumina-basic,	61·99
Water,	18·29
	100·00

This mineral, when treated with a sufficient quantity of sulphuric acid dissolves, and is converted into the crystallizable alum of commerce.

The true composition of alum has not long been understood. VAUQUELIN and CHAPTAL appear to have been the first chemists who ascertained, by decisive experiments, that alum was composed of sulphuric acid, alumina, and potassa, ammonia, or soda, united.

The celebrity acquired by alum among the ancients, as a substance extremely useful in dyeing and medicine, was entirely forgotten at the time the alum of the moderns became known; but it was again revived when it was discovered that real alum could be extracted from minerals containing sulphur compounds, or that where the latter are found there are generally minerals abounding with it. In many of these places, alum-works have, in the course of time, been erected; and, as BECKMANN ingeniously remarks, this circumstance has served, in some measure, to strengthen the opinion that the alum of the ancients and of the moderns is synonymous; because, where the former was found, the latter has since been procured by a chemical process. Some historians of the fifteenth century even speak of the alum-works as if the manufacture of this salt had only been revived in Europe.

Alum owes its high estimation to its beneficial use in the art of dyeing, in which it is employed as a mordant. The Italians procured their first alum from the Levant, along with other materials; but when these countries were taken by the Turks, it grieved the Christians to be compelled to purchase these necessary materials from the common enemy. In due time the Italians became acquainted with the art of boiling alum, and when they at length discovered aluminous minerals in their own soil, these were soon brought into use, which caused the Turks to abandon many of their alum-works. The modern alum was, in the beginning, distinguished from the ancient by the denomination of *rocca*.

DUCAS describes very minutely the alum-work at Foya Nova, near Smyrna; but that work has been long since abandoned. Drs. FRANCIS and GRIFFITH state, that in Phocis, lying close to Ionia, there is a mountain rich in aluminous mineral. The stones found at the summit are first calcined in the fire, and then reduced to powder by throwing them into water. The moist mass is put into a kettle, a little more water added, and the whole having been made to boil, the powder is lixiviated, the thick part which falls to the bottom in a cake is preserved, and the hard and earthy portions are discarded. The cake is afterwards allowed to dissolve in vessels for four days, at the end of which the alum is found in crystals around their edges, and their bottoms are also covered with the salt; the remaining liquor is poured into a kettle, diluted with water, and more powder added, then boiled as before, and put into proper vessels to crystallize. The alum obtained in this manner is preserved as an article very necessary for dyers. Captains of ships bound from the Levant to Europe, consider alum as a very convenient and useful cargo for their vessels.

The alum-works near Civita Vecchia are, by Italian historians, asserted to have been the first in Europe—they are the oldest carried on at present. They were founded by JOHN DI CASTRO, who has been already mentioned as learning the process near Constantinople. He was there at the time the superb city fell into the hands of the Turks, trading in Italian cloths and dye-stuffs; after this he returned to his own country, and having found, in the neighborhood of Tolfa, a plant which he had observed growing abundantly in the aluminous districts of Asia, he conjectured that the virgin soil might also contain the same salt, and the astringency of its taste proved he was correct. On this discovery, factories were immediately erected, the produce of which was vended to the Venetians, the Florentines, and the Genoese. The stones were first calcined, a large quantity of water was then thrown over them, and when they were entirely dissolved, the lie was boiled in great leaden caldrons; after which, it was run into wooden vats and allowed to evaporate spontaneously; the result was alum of the most perfect kind. Pope PIUS the Second employed more than eight hundred persons in preparing it. BECKMANN continues—The plant which first induced CASTRO to search for alum was the prickly evergreen, *Ilex aquifolium*, which in Italy is still considered as an indication that the regions where it thrives abound with alum. This shrub, or holly, is, however, frequently found growing where there is not the slightest trace of this salt.

It appears, from all that can be learned, that the art of boiling alum was first understood in Italy, but not previous to 1548. The great revenue which the Apostolic Chamber derived from alum induced many to seek aluminous minerals, and factories were built wherever such were found. The Pope, however, understood his own interest so well, that he never rested until he had caused all the works erected in the other territories to be discontinued, by which he alone remained master of the prize. Like all tyrants, he endeavored, by every possible means, to prevent foreigners acquiring any knowledge of the art. His commerce increased more and more, and he instructed his menials to demand exorbitant prices for the salt, so that foreigners purchased from the Spaniards and Turks. The ban of excommunication was threatened in case any one should be so unchristian as to purchase alum from the infidels; while every person was at liberty to make what bargain he liked with the Bishop of Rome for this commodity! But these measures, like all those founded on the simplicity of others, could not long be endured; as soon as men became more enlightened, they saw through the duplicity of the head of the Romish Church, and discovered the selfishness of his bulls. Alum-works soon appeared in Germany, and, in 1554, at Oberkaufungen, in Hesse, a factory was in full operation. In England, the first alum-work was erected at Gisborough, in Yorkshire, where Sir THOMAS CHALONER had an estate. The knight engaged workmen well versed in the Roman alum business, because there was no one in England who then understood its facture. It is said that, as soon as the Pontiff heard this, he endeavored to recall the renegades by threats and anathemas. These, however, were of no avail, and did no injury to the heretics; in a short time the manufactory was most flourishing, and several more of the same kind were soon after established. PENNANT, in his Scotch Tour, has the following:—The alum-works in this country are of some antiquity; they were first established in the reign of Queen ELIZABETH, by Sir THOMAS CHALONER, who, observing the trees tinged with an unusual color, made him suspicious of its being owing to some mineral in the neighborhood. He ascertained that the strata abounded with an aluminous salt. At that time the English, being strangers to the method of managing it, there is a tradition that Sir THOMAS was obliged to seduce some workmen from the Pope's alum-works, then the greatest in Europe. If one may judge, from the curse which his Holiness thundered out against the knight and his fugitives, he certainly was not a little enraged; for he cursed without varying a tittle from that most comprehensive of imprecations left us by ERNULPHUS. The first pits were near Gisborough, the seat of the CHALONERS, who still flourish there, notwithstanding the Bishop of Rome's interdictions.

Before entering minutely into the fabrication of alum, it will be proper to state how and where the salt is obtained. The greater portion of the alum in this country is manufactured from alum-slate—a bituminous schist containing sulphide of iron diffused in very fine particles throughout its mass; it has a bluish or greenish-black color, and eliminates sulphurous acid when burned, acquiring thereby an aluminous taste. Many of the alum-slates crumble to pieces, or suffer disintegration, on exposure to the air; their sulphur becomes gradually converted into sulphuric acid, by absorbing oxygen from the atmosphere, while, simultaneously, the iron is sesquioxidized, and having in this state a very feeble affinity for the sulphuric acid, parts with the greater portion to the clay, which is thereby converted into sesquisulphate of alumina, and this, when combined with sulphate of potassa, constitutes the alum of commerce. Alum may be prepared by decomposing clay with sulphuric acid; the decomposition is effected in as complete a manner by calcining pure clay, grinding the adusted mass to powder, and mixing it with about half a per cent. of sulphuric acid. This mixture is then to be heated in a furnace till the mass becomes very thick; afterwards left to repose for a month or more, and then affused with water, to wash out the sulphate of alumina. The addition of a potassa salt converts it into alum.

Graham states that the old method of making alum is still largely practised in this country:—A series of beds occur low in many of the coal measures, which contain much bisulphide of iron. One of these, known as alum slate, is a siliceous clay, containing a considerable portion of coaly matter, and of the metallic sulphide in a state of minute division. When this mineral is exposed to air and moisture, it soon exfoliates, from the formation of sulphate of iron, the bisulphide of iron absorbing oxygen like a pyrophorus. The excess of sulphuric acid formed, attacks the other bases present, of which the most considerable is alumina. Aluminous schists often require to be moderately calcined or roasted, before they undergo this change in the atmosphere. The mineral being lixiviated, after a sufficient exposure, affords a solution of sulphate of alumina and protosulphate of iron, from which the latter salt is separated by crystallization. The subsequent addition of sulphate of potassa to the liquor, causes the formation of alum; the chloride of potassium answers the same purpose, and has the advantage over the sulphate, that it converts the remaining sulphates of iron into chlorides, which are very soluble, and from which the alum is most easily separated by crystallization.

Alum requires about eighteen parts of cold, and less than one part of boiling water to dissolve it, and crystallizes very readily in large regular octahedrons, of which the apices are always more or less cut off. Its taste is sweetish, and very astringent. It is an acid salt, reddens vegetal blues, and dissolves metals with evolution of hydrogen; it slightly effloresces in the air, and at a gentle heat suffers the aqueous fusion. Its water of crystallization amounts to 45·5 per cent. of its weight, or twenty-four atoms. The fused salt, in losing this water, becomes viscid, and intumesces, leaving calcined or burnt alum, which is sometimes used as a corrosive.

The octahedral crystals of potassa alum consist of sulphuric acid, alumina, potassa, and water, in the annexed proportions:—

	Atomic weight.		Centesimally represented.
1 Eq. Sesquisulphate of alumina,.........	172	....	36·21
1 Eq. Sulphate of potassa,...............	87	....	18·31
24 Eq. Water,.........................	216	....	45·48
1 Eq. Crystallized potassa alum,.........	475		100·00

Or of—

1 Eq. Alumina,.........................	52	....	10·94
1 Eq. Potassa,.........................	47	....	9·89
4 Eq. Sulphuric acid,.....................	160	....	33·68
24 Eq. Water,.....	216	....	45·49
1 Eq. Crystallized alum,..................	475		100·00

Formula,......$Al_2\,O_3\;3\,S\,O_3,\;K\,O,\;S\,O_3 + 24$ aq.

The solubility of this salt is, according to **Poggiale**, as follows:—

100 parts	of water at	32°,	dissolve	3·29	parts of alum.
"	"	50	"	9·52	"
"	"	86	"	22·00	"
"	"	140	"	31·00	"
"	"	158	"	90·00	"
"	"	212	"	357·00	"

At a white heat, all the sulphuric acid in combination with the alumina, and the water of crystallization, pass off, leaving a mixture of the earth and sulphate of potassa. When crystals of alum are heated in a retort, an acid solution—spirit of alum, according to the old chemists—distils over and collects in the receiver. Potassa alum, on being ignited with charcoal, is converted into a pyrophorus.

Alum, when heated with alkaline chlorides, liberates hydrochloric acid; again, if a concentrated solution of this salt is boiled with chloride of sodium or potassium, the same acid is given off, and a sparingly soluble basic alum precipitated. **Richter** states that a solution containing alum, chloride of sodium, and nitrate of soda, is a solvent for gold.

When alum is dissolved in twenty parts of water, and ammonia dropped slowly into the solution till the liquid is nearly saturated, a bulky white precipitate appears, which, when thoroughly edulcorated with distilled water, is pure alumina. If dried and weighed, it will be found to be 10·82 per cent. of the weight of the alum taken. If this earth, while moist, be dissolved in dilute sulphuric acid, it will constitute, when as neutral as possible, the sulphate of alumina, which requires only two parts of cold water for solution. If this solution be now decomposed by pouring into it liquid ammonia, there appears an insoluble white powder—subsulphate of alumina or basic alum. It contains three times as much earth as the neutral sulphate. However, by adding a strong solution of sulphate of potassa to that of the neutral sulphate, a white powder will fall, which is true alum. When recently-precipitated alumina is boiled in a solution of alum, a portion of the earth enters into combination with the salt, constituting the insoluble compound which falls as a white amorphous powder: the same combination occurs if a boiling solution of alum be decomposed by potassa.

These experimental facts develop the principles of the manufacture of alum, which is prosecuted under various modifications for its important uses in the chemical arts.

MANUFACTURE OF ALUM.—Two alums, only, are applied in the arts; these are composed of sesquisulphate of alumina, in combination with sulphate of potassa, or sulphate of ammonia, or both, as given in the annexed formulæ:—

$$K\,O,\quad S\,O_3 + Al_2\,O_3,\ 3\,S\,O_3 + 24\ \text{aq.}$$
$$Am\,O,\quad S\,O_3 + Al_2\,O_3,\ 3\,S\,O_3 + 24\ \text{aq.}$$
$$\left.\begin{matrix}K\,O\\ Am\,O\end{matrix}\right\}\,S\,O_3 + Al_2\,O_3,\ 3\,S\,O_3 + 24\ \text{aq.}$$

The first of these, potassa alum, is simply called alum amongst practical men, whilst the second variety is distinguished by the name of *ammonia alum.* The latter is easily distinguished from the former by its giving out the odor of ammonia when triturated with quicklime. The potassa alum is preferred by turkey-red dyers; but both are used by dyers and calico-printers solely for their alumina, and in this particular they are accounted nearly of equal value; the other constituents being almost useless. The possibility, however, of producing a cheap and pure salt of alumina in large quantities, is dependent on the property alum possesses, of separating from its concentrated solutions in large, well-defined crystals; the purity of the alumina in this salt, and which is necessary in the applications of alum, enables the purchaser to pay for the sulphuric acid, water, and alkali, although they are useless, except for effecting the crystallization. Sulphate of alumina is with great difficulty separated from many other extraneous salts that accompany it in the manufacture, particularly from sulphate of iron, whilst alum, from the ease with which it dissolves in hot water, and its sparing solubility in cold, is readily separable from any adventitious substances.

Production of Alum from Alum Stone.—Alum is obtained in much larger quantity from alum rock, a formation of volcanic origin, than from any other source. This is a massive, granular, only partially crystalline, transparent, and not homogeneous rock, which frequently encloses quartz, sometimes iron pyrites, and manganese ore. Its color is yellowish, passing into green, grey, red, or brown. The pure mineral alum stone, *alunite*, sometimes occurs in it in distinct crystals, which have been found to consist of a basic sulphate of alumina, with sulphate of potassa, and is, therefore, a basic alum, or, more probably, a combination of neutral sulphate of alumina and potassa, with hydrate of alumina, $KO, SO_3 + Al_2O_3, 3SO_3 + 2Al_2O_3, 3HO$.—*Rammelsberg*. It differs, therefore, from alum, in containing an excess of alumina. Alum rock is of the same nature—a massive alunite, but of a less pure character; it is found at Tolfa, near Civita-Vecchia, in the Papal States; at Montione, in the dukedom of Piombino; in the Comitats, Beregh, and Zemplin, in Hungary; at Mont d'Or, in France; and in the Greek islands, Milo and Nipoglio; but is not of very common occurrence in other places. The analyses of this rock have yielded the following results:—

	From Tolfa, by Klaproth.	From Beregszaz, by Klaproth.	From Montione, by Descotil.	From Mont d'Or, by Cordier.
Silica,................	56·5	62·3	—	28·4
Alumina,..............	19·0	17·5	40·0	31·8
Sulphuric acid,........	16·5	12·5	35·6	27·0
Potassa,..............	4·0	1·0	13·8	5·8
Water,................	3·0	5·0	10·0	3·7
Sesquioxide of iron,....	—	—	—	1·4
Loss,.................	1·0	1·7	0·6	1·9
	100·0	100·0	100·0	100·0

It will be seen from these analyses, that, overlooking the silica, there is chiefly a deficiency of potassa, and also of sulphuric acid, in the rock, for the formation of alum; but, in the mineral from Tolfa, for instance, there is about three per cent. of sulphuric acid, and fourteen per cent. of alumina, more than are requisite to form alum with the four per cent. of potassa. The alum stone from Beregszaz also contains an excess of nine per cent. of acid, and sixteen per cent. of earth; that from d'Or, six per cent. of acid, and twenty-five per cent. of alumina. At Tolfa, where the alum stone comes to the surface, a quantity of alum is produced proportionate to the amount of potassa in the rock, and the remainder, particularly the excess of alumina, is separated. This is effected by burning the stones in heaps, or furnaces, similar to those used in preparing gypsum—Fig. 86—particular care being taken that the temperature does not rise too high.

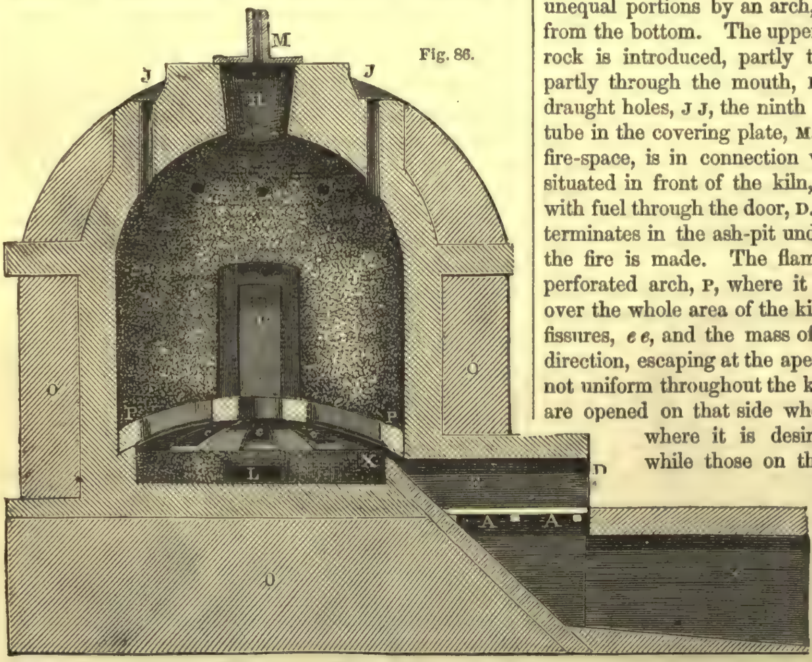


Fig. 86.

The inner chamber of this kiln is divided into two unequal portions by an arch, P P, situated about a foot from the bottom. The upper part, into which the alum rock is introduced, partly through the door, G, and partly through the mouth, H, is provided with eight draught holes, J J, the ninth hole being formed by the tube in the covering plate, M. The lower chamber, or fire-space, is in connection with the fire, E, which is situated in front of the kiln, and which is replenished with fuel through the door, D. The draught-channel, C, terminates in the ash-pit under the grate, A, on which the fire is made. The flame enters at X, below the perforated arch, P, where it is uniformly disseminated over the whole area of the kiln, and passes through the fissures, *e e*, and the mass of materials, in an upward direction, escaping at the apertures, J J. If the heat is not uniform throughout the kiln, the draught-holes, J J, are opened on that side where it is least intense, and where it is desirable to lead the flame, while those on the other side are closed. The aperture, L, is used for clearing the fire-chamber, and is closed, as well as G and H, during the firing. Particular attention is given to the maintenance of a proper temperature. O O represent the exterior walls of the kiln, made of non-conducting materials to secure the retention of the heat.

At a red heat, sulphate of alumina is decomposed, yielding, partly anhydrous sulphuric acid, and partly oxygen and sulphurous acid. As soon as these vapors appear, the burning is stopped, and the mass is transferred to walled cisterns, where it is repeatedly moistened with water, which collects below, and is allowed to disintegrate for three or four months, at the expiration of which period it is converted into a soft mud, tasting perceptibly of alum, which may then be dissolved out with water. If the alum stone contained an excess of hydrate of alumina, this would infallibly react upon the alum, and form with it a similar but insoluble compound, containing basic sulphate of alumina—the burning expels the water from the hydrate of alumina, and thus renders it chemically inactive; the excess of alumina is thus separated from the compound, which then yields an alum soluble in water. During the evaporation—until the specific gravity is 1·114 at 113° Fahr.—the lie still holds a fine ferruginous rose-red powder in suspension, which feebly colors the crystals, but is left when these are redissolved. The crystals contain potassa, but no ammonia, and are highly prized in commerce, under the name of *Roman alum.*

PRODUCTION FROM ALUM ORE.—The production of alum from alum shale and alum earth is systematically carried out or divided into three distinct operations: the production of sulphate of alumina; the addition of sulphate, or chloride, of the alkali to the concentrated cold solution of the former, in which operation the difficultly soluble alum precipitates in the form of powder, and is thus separated from the foreign salts; and, lastly, the purification of the alum flour by recrystallization.

Alum shale is a kind of clay slate impregnated with sulphide of iron and bituminous matters—a member, therefore, of the younger transition series of rocks—allied to real clay slate by its firmness, appearance, slaty structure, and great extent. Although it is not so abundantly disseminated as other species of rocks and minerals, it forms, nevertheless, beds of considerable extent in many localities, particularly in the Scandinavian peninsula in Bohemia; in the Hartz, in Upper Bavaria; in Voigtland, in the mountainous districts of the Lower Rhine; in England, near Whitby; in Scotland, at Hurlet and Campsie, near Glasgow; in the Uralian Mountains. It may be also met with in many other districts, but not in sufficient quantity to be available for practical purposes.

The following analyses show the composition of the rocks:—

Alum Shale from Siehda, by Lampadius.

Sesquisulphate of alumina,	2·68
Potassa alum,	0·47
Sulphate of iron,	0·95
Sulphate of lime,	1·70
Silica,	10·32
Alumina,	9·21
Magnesia,	traces
Sesquioxide of iron,	2·30
Oxide of manganese,	0·31
Sulphur,	7·13
Water,	33·90
Carbon, *et cetera*,	31·03
	100·00

Alum Shales, by G. Kersten.

	Hermannsschachte.	Gluckaufgang.	Blucherschachte.
Carbonaceous matters,	41·10	27·92	34·20
Silica,	44·02	51·32	50·21
Sesquioxide of iron,	6·23	8·40	0·42
Alumina,	5·60	7·62	5·21
Magnesia,	0·32	0·26	0·53
Oxide of manganese,	0·12	traces	traces
Sulphur,	1·25	2·89	1·72
Sulphate of lime,	traces	traces	traces
Loss,	1·36	1·59	7·71
	100·00	100·00	100·00

Alum Shales, by Erdmann.

Soluble in acid.	Garnsdorff.		Wezelstein.	
Sulphide of iron,	7·533		10·166	
Silica,	0·060		0·100	
Sesquioxide of iron,	0·966		2·466	
Alumina,	1·833		3·166	
Lime,	0·400		1·000	
Magnesia,	trace		1·022	
		10·792		17·920
Insoluble in acid.				
Silica,	50·066		52·200	
Alumina,	8·900		17·900	
Sesquioxide of iron,	1·300		3·366	
Magnesia,	1·000		1·133	
Lime,	trace		trace	
Coal,	22·833		0·803	
		84·099		75·402
Loss,		5·109		6·678
		100·000		100·000

Subjoined is the composition of several shales which are sometimes used in the manufacture of alum:—

	Locality unknown. D'Aubisson.	Dunmeniss, Devonshire. Stokes.	Gaggenan, Baden. Holtzmann.	Niedesselten, Nassau. Wimph.	Goslar, Hartz. Frick.	Brenndaff, N. Coblentz. Frick.	Lehsten, Thuringerwald. Frick.	Prague. Plerschl.
Silica,	48·6	59·4	64·34	79·17	60·03	62·83	64·57	67·50
Alumina,	23·5	17·4	23·90	10·42	14·91	17·11	17·30	15·89
Sesquioxide of iron,	11·3	11·6	9·70	6·27	8·94	8·23	7·46	5·85
Oxide of manganese,	0·5	—	—	—	—	—	—	0·08
Lime,	—	2·1	—	—	2·08	0·83	1·16	2·24
Magnesia,	1·6	2·2	—	—	4·22	1·90	2·60	3·67
Potash,	4·7	—	—	—	3·87	4·17	1·99	1·23
Soda,	—	—	—	—	—	—	—	2·11
Strontia,	—	—	—	—	—	—	—	0·30
Oxide of copper,	—	—	—	—	0·28	0·27	0·30	—
Fluoride of calcium,	—	—	—	—	—	—	—	} 1·13
Phosphoric acid,	—	—	—	—	—	—	—	
Sulphur,	0·1	—	—	—	—	—	—	—
Carbon,	0·3	—	—	—	—	—	—	—
Carbonic acid,	—	—	—	—	} 5·67	4·66	4·62	—
Water,	7·6	6·4	2·22	2·78		—	—	—
Loss,	1·8	0·9	—	1·36	—	—	—	—
	100·0	100·0	100·16	100·00	100·00	100·00	100·00	100·00

The annexed is the composition of some shales from Whitby, in Yorkshire, and Campsie, near Glasgow:—

	Whitby. Richardson.			Campsie.			
	Top rock.	Bottom rock.		Top rock.	Top rock.		Bottom rock.
Sulphide of iron,	4·20	8·50	Sulphur,	22·36	23·44	Pyrites,	9·63
			Iron,	18·16	15·04		
Silica,	52·25	51·16		15·40	15·40		0·47
Protox. of iron,	8·49	6·11		—	—		2·18
Alumina,	18·75	18·30		11·35	11·64		18·91
Lime,	1·25	2·15		1·40	2·22		0·40
Magnesia,	0·91	0·90		0·50	·32		2·17
Oxide of manganese,	traces	traces		0·15	—		0 55
Sulphuric acid,	1·37	2·50		—	—		0·05
Potassa,	0·13	traces		0·90	—		1·26
Soda,	0·20	traces		—	—		0·21
Chlorine,	traces	traces		—	—		—
Coal,	4·97	8·29	Carbon and Loss,	29·78	Carbon, 28·80		8·51
Water,	2·68	2·00		—	—		8·54
Loss,	4·80	8·09		—	3·13		0·59
	100·00	100·00		100·00	99·99		100·00

The Campsie alum ores, especially the upper, contain a large excess of pyrites, yielding of course more sulphuric acid than the alumina can take up, while the lower have a considerable excess of alumina; it is, therefore, the object of the manufacturers of alum to mix these ores in such a manner that the different ingredients may be made available as far as possible.

The composition of the residue from the Campsie ores, after calcination and washing out the alum, is:—

Silica,	38·40
Alumina,	12·70
Sesquioxide of iron,	20·80
Oxide of manganese,	traces
Lime,	2·07
Magnesia,	2·00
Potassa,	1·00
Sulphuric acid,	10·76
Water,	12·27
	100·00

It is well known that alum earth belongs to the more recent deposits, occurring below the first strata of the tertiary coal formation, which are of a later period than the chalk. It is a massive but soft pulverizable mass, stratified, but not slaty, and of a dark-brown color; it occupies basins of variable dimensions, according to the position of the neighboring rocks. Very large deposits of this formation occur in the valley of the Oder, and are worked at Freienwalde and Muskau. It is no uncommon phenomenon, in the coal formations, for the clay and coal strata to permeate each other in those localities where they meet. These deposits, which frequently cover the coal formation, and are, at other parts, in alternate layers with the coal, play the part of alum ores, and may be worked for the production of alum, when they contain a sufficient quantity of sulphide of iron, which is often the case. To this class belong the Scotch ores. In Upper Silesia it is even found profitable to make the refuse coal, or *brees*, which cannot well be used as fuel, subordinate to the production of alum; these coals leave an aluminous ash, and those which are rich in iron pyrites are only distinguished from a real alum ore by their large excess of combustible matter, and which, in this case, cannot be turned to account.

Iron pyrites, or the bisulphide of iron—$Fe\ S_2$—is quite as indispensable to the production of alum as alumina itself. This compound is formed by the decomposition of protosulphate of iron—$Fe\ O,\ S\ O_3$—held in solution in water by the fossil coal. Green vitriol, or protosulphate of iron, is deprived of oxygen by an organic substance being retained for a length of time in contact with it, and becomes reduced to sulphide of iron. The sulphide is disseminated through the alum ores, partly in the well-known brilliant yellow crystals, or crystalline deposits, but chiefly in a very fine state of division, as a dull, black powder, somewhat resembling the mass obtained by precipitating a salt of iron by sulphide of ammonium. Hence, inasmuch as it was not perceptible to the eye, its presence has not only been overlooked in the following analyses, but actually denied:—

	Alum earth.	
	From Freienwalde. Klaproth.	From Putzberg. Bergmann.
Alumina,	16·00	10·90
Silica,	40·00	45·40
Magnesia,	0·25	—
Sulphur,	2·85	3·94
Carbon,	19·45	5·95
Protoxide of iron,	6·40	5·50
" manganese,	—	0·60
Protosulphate of iron,	1·80	5·73
Sulphate of alumina,	—	1·20
" lime,	1·50	1·71
" potassa,	0·50	1·75
Chloride of potassium,	0·50	0·35
Sulphuric acid,	—	0·47
Water,	10·75	16 60
	100·00	100·00

The sulphur is in combination with the iron, and not, as was formerly supposed, in the free state, or as sulphide of carbon. Although the constituents of alum earth are nearly the same in specimens taken from other localities, the proportions are nevertheless variable, as might have been expected from the mode in which the deposits are formed; so great, indeed, is the difference in this respect, that the examples given above can hardly be viewed as a fair average of these compounds. Pyrites and alum ores owe the property of being rapidly decomposed under the influence of atmospheric air to the fine state of division of the bisulphide, and probably, also, to the occasional presence of the protosulphide of iron. Massive crystalline pyrites is very slowly decomposed under the same circumstances. The decomposition is occasioned by seven equivalents of oxygen being taken up by the pyrites—$Fe\ S_2$—which convert it into protosulphate of iron and sulphuric acid—$Fe\ O,\ S\ O_3$, and $S\ O_3$. This combination of the oxygen with the iron and sulphur, is induced by contact of oxygen, and a spontaneous rise of temperature which results from the chemical union; when the latter becomes more developed, it converts the sulphide of iron, as by roasting, into protosulphide and sulphur, which immediately burn, the former being resolved into protosulphate of iron, and the latter into sulphurous acid, which is absorbed by the alumina. The sulphite of alumina thus formed is easily changed, by absorption of atmospheric oxygen, into sulphate of alumina; or, as RICHARDSON justly remarks, what is more likely, by reducing the sesquisulphate to the state of sulphate of the protoxide. The alum ore, when first taken from the ridges—calcined heaps—and covered with water, which is removed after a short interval, will be found to have yielded little sulphate of alumina to the solution, but a great deal of sesquisulphate of iron; while, after being allowed to remain for some time over the ore, the solution will be found to contain much sulphate of alumina and protosulphate of iron: alum-makers know that the first washes are not those which afford the most alum, unless the ore has been permitted to remain in the steeps for a length of time; they are also aware that more alum is procured by adding to the lie a portion of *mothers*, which are very rich in sesquisulphate of iron, than is obtained by pure water, *per se*.

The sulphides of iron are, therefore, available to the production of alum merely by affording the necessary amount of sulphuric acid to unite with the alumina; besides the acid produced by the second portion of sulphur in the bisulphide, another portion is combined with alumina by the decomposition of the green vitriol, the protoxide of iron in which is speedily converted into sesquioxide by the oxygen of the air, and is precipitated in the form of a basic salt. Potassa, which is never altogether wanting in the alum ores, gives rise in a similar manner to the liberation of sulphuric acid by the production of basic sulphate of potassa and iron; sesquisulphate of iron is also decomposed by hydrate of alumina, and sulphate of alumina dissolves, but the greater portion remains insoluble with the basic sulphate of iron.

Lime in the ores is most prejudicial, for this base deprives the sulphate of alumina and sulphate of iron of their sulphuric acid, and entirely puts a stop to the production of alum; ores containing any considerable quantity of lime, cannot, consequently, be used in this manufacture. Gypsum, however, is always found in the crude lies. Magnesia is no less deleterious to the formation of alum, but the sulphate of magnesia—Epsom salt—thus produced, is not totally valueless. In some of the English alum-works, the Epsom salt is a most important object. Fresh alum ores contain no soluble salts of alumina or iron; it is only where air has had access to them, either in the pit or at the surface, that efflorescence in the form of fine needles—feather alum—is observed, and this consists partly of real alum, partly of sulphate of alumina, or of combinations of the latter salt with protoxide of iron, sulphate of magnesia or other salts.

An aluminous sulphate of iron occurred abundantly some years ago in the Hurlet and Campsie wrought-out coal beds, which had the following composition:—

	Berthier.	Phillips.	R. D. Thomson.	R. D. Thomson.
Sulphuric acid,..	34·40	30·90	35·600	28·635
Protoxide of iron,	12·00	20·70	13·560	19·935
Alumina,.......	8·80	5·20	7·127	2·850
Magnesia,......	0·80	—	—	—
Water,.........	44·00	43·20	43·713	48·580
	100·00	100·00	100·000	100·000

The composition of this feather alum, or ***hair-salt***, as it is termed in different localities, is shown by the subsequent analyses. The term hair-salt, sometimes given to these natural effloresced bodies, belongs more properly to the sulphate of magnesia often accompanying them.

COMPOSITION OF NATURAL SULPHATE OF ALUMINA—FEATHER ALUM.

	Saldana.	Pasto.	Pyromeni, in Island Milo.	Coquimbo, Chili.	Kolosorak, Bohemia.	Friersdorff, near Bonn.	Potschappel, near Dresden.	Freienwalde.	Ararat.	Andes.	Campsie, Glasgow.
	Columbia.										
Sulphuric acid,........	36·400	35·68	40·31	36·97	35·82	37·380	35·710	35·637	58·58	35·872	40·425
Alumina,.............	16·000	14·98	14·98	14·63	15·57	14·867	12·778	11·227	38·75	14·645	10·482
Sesquioxide of iron,....	0·004	—	—	2·58	—	—	—	—	—	0·500	8·530
Protoxide of iron,......	—	—	—	—	—	2·463	0·667	·718	$\left.\begin{matrix}SO_3\\FeO\end{matrix}\right\}$ 2·78	—	—
Protoxide of manganese,	—	—	—	—	—	—	1·018	0·307	—	—	—
Potassa,.............	—	—	0·26	—	—	0·215	0·324	0·430	—	—	1·172
Soda,................	—	—	1·13	—	—	—	—	—	—	2·262	--
Lime,................	0·002	—	—	—	—	0·149	0·640	0·449	—	—	—
Magnesia,............	0·004	—	0·85	0·14	—	—	0·273	1·912	—	—	—
Hydrochloric acid,.....	—	—	0·40	—	—	—	—	—	—	—	—
Silica,..............	—	—	1·13	1·37	—	—	—	0·430	—	0·100	—
Water,...............	46·600	49·34	40·94	44·64	48·61	45·164	47·022	48·847	—	46·375	36·295
Loss,................	0·990	—	—	—	—	—	1·568	·043	—	0·246	3·096
	100·000	100·00	100·00	100·33	100·00	100·238	100·000	100·000	100·11	100·000	100·000
	Boussingault.		Hartwell.	H. Rose.					Gobel.	T. Thomson.	

The manufacture of alum from alum schists may be distributed under the six following heads:—

Preparation of the alum slate.
Lixiviation of the ustulated slate.
Evaporation of the lixivium.
Addition of the saline ingredients.
Edulcoration of the aluminous salts.
Crystallization.

Preparation of the Alum Slate.—Roasting or Ustulation.—Some alum slates are of such a nature that, being piled in heaps in the open air, and moistened from time to time, they get spontaneously hot, and by degrees fall into a pulverulent mass, ready to be lixiviated. The greater part, however, require the process of ustulation, from which many advantages are derived. The cohesion of the dense slates is thereby so much impaired, that their disintegration becomes more rapid; the decomposition of the pyrites is quickened by the expulsion of a portion of the sulphur; and the ready-formed sulphate of iron is partly decomposed by the heat, with a transference of its sulphuric acid to the clay, and the production of sulphate of alumina.

Such alum slates as contain too little bitumen, or coal, for the roasting process, must be interstratified with layers of small coal or brushwood. The fuel being kindled, the whole slowly ignites. More rock is piled upon it, until, in some instances, a vast heap of inflamed material, one hundred feet high, and two hundred feet square, is raised, which continues to burn for months. When the heap is fired with brushwood, its ash, yielding potassa, gives rise to the formation of small quantities of alum.

Alum is manufactured at Whitby by the combustion of the schists of the upper lias, which contain a quantity of iron pyrites and bituminous or carbonaceous matter. The temperature being regulated, and water occasionally supplied, decomposition occurs, producing sulphates of alumina, iron, and magnesia—*exempli gratia*—

$$4\,Fe\,S_2 + Al_2\,O_3 + Mg\,O + O_{28} = 4\,Fe\,O, S\,O_3 + Al_2\,O_3, \\ 3\,S\,O_3 + Mg\,O, S\,O_3.$$

In Rhenish Prussia, especially at Salzweiler, the ustulation is effected spontaneously, by the aid of a stratum of brown coal beneath it, which has continued in a state of incipient and restricted combustion ever since 1660, when it was accidentally ignited.

A clay bottom is well adapted for the erection of a heap, to prevent any of the salts being carried by the moisture into the soil; the heap is also sometimes constructed under a shed. As a general rule, the produce is better the slower and more uniform the heat during the calcination.

The Scotch alum-works are those of Hurlet and Campsie—the former six miles South from Glasgow, the latter about nine miles North of the city, at the foot of the Campsie Hills. Mr. KING, of the Campsie works, is also proprietor of one of the establishments at Hurlet; the other belonging to Messrs. JOHN WILSON and SONS. The two factories at Hurlet embrace an area of eighteen to twenty acres, the greater portion of the space being occupied by the calcining fields. The aluminous shale found in this locality is interstratified between the coal bed and the limestone, and is nearly as dark-colored as the former; it is occasionally found mixed with native crystals of sulphate of iron. After the shale has been exposed to the air for some time, the black color is replaced by a grey, owing to the action of the air causing it to throw out a white efflorescence of alum.

A striking appearance is presented by the alum-field, which is covered throughout with ridges or elongated mounds of the ore for calcination, or already calcined, and these assume a reddish-brown hue from the effect of the heat. The heaps vary in size, being from six thousand to about twenty thousand tons in content. At one of the works under consideration, there are about fifteen of the mounds or ridges of shale, each being one hundred and twenty to one hundred and eighty feet in length, with a base of about twenty feet, and a height of fifteen.

Fig. 87 shows the arrangement of the field.

The mounds are commenced by making a few fires of coal along the intended length, and covering them over with stones or bricks in any convenient manner, leaving lateral ducts, or passages, for the air to enter. Next, the shale is thrown on the fires, the coarsest first; and according as it ignites, and communicates heat to the outer portions, more of the mineral is thrown upon it successively, till the heap is considered large enough, so as to have the whole at that state of ignition which practice leads the manager to judge most advantageous. It is then *mantled*, as the workmen term it, that is, covered over with a layer of the already calcined and exhausted ore, in order to protect it from high winds and excessive rains, as also to moderate the heat and let it cool gradually, so that the sulphur present may not be volatilized or sublimed. From three to twelve months, according to the state of the weather, are generally required to calcine the heap properly; and in rough weather very little progress is made: this time includes the period of cooling the burned ore, which is done either by leaving the heap to itself, or checking the ustulation with a thicker mantling.

By an economical arrangement of the manager, the several mounds are in various stages of advancement, some being cold, others about being finally mantled for cooling, many in progress, while a further number are commencing, so that at all times a supply of calcined shale may be ready for the liquefying vats.

At Whitby, the calcining heaps are raised from eighty to a hundred feet in height. In consequence of the greater amount of carbonaceous matters which the shale at these works contains, the temperature of the mounds rises too high, and causes a loss on account of the excess of sulphurous and sulphuric acids sublimed; this is partly prevented by mixing the shale with some of the calcined and exhausted ore, and when the heap has acquired a larger size, and the heat is still deemed too high, either the crevices are plastered up with the small schist, or the whole is mantled over as at Hurlet. It would appear that the height of the heap must be disadvantageous to the manufacturer, on account of the difficulty of properly regulating the heat in so large a mass of material, and that the method followed at the Hurlet works effects a better ustulation, while at the same time it is more under control.

About one hundred and thirty tons of the Whitby calcined schist yield one ton of alum. In this humid climate it is found advisable to pile up on the top of the ridge of brushwood or coal and schist, a pyramidal heap of the mineral, which, having its surface plastered smooth, with only a few air-holes, protects the mass from the rains, and at the same time prevents the combustion from becoming too vehement. Should heavy rains supervene, a gutter must be scooped out round the pile for receiving the aluminous lixivium, and conducting it into the reservoir.

A continual but very slow heat, with a smothered fire, is most beneficial for the ustulation of alum slate. When the fire is too brisk, the sulphide of iron may run with the earthy matters into a species of slag, or the sulphur will be dissipated in vapor, both of which accidents would cause a deficiency in the produce of alum. Those bituminous schists which have been used as fuel under steam boilers, have suffered such a violent combustion, that their ashes scarcely yield any alum. Even the best regulated calcining piles are apt to burn too briskly in high winds, and should have their draught-holes carefully stopped under such circumstances. It may be laid down as a general rule, that the slower the combustion the richer will the roasted ore be in sulphate of alumina. When the calcination is complete, the heap diminishes to one half its original bulk; it is covered with a light reddish ash, and is open and porous in the interior, so that the air can circulate freely throughout the mass. To favor this access of air is another reason that the masses should not be too elevated; and in dry weather a little water should be occasionally sprinkled on them, which, by dissolving some of the saline matter, will make the interior more open to the atmosphere.

When the calcined mineral becomes thoroughly cold, it may be submitted to the lixiviating vats. As many weeks, or even months, may elapse, from the first construction of the piles or beds till their complete calcination, care ought to be taken to provide a sufficient number of them, so as to have an adequate supply of material for carrying on the lixiviating and crystallizing processes during the course of the year. The beds are known to be sufficiently decomposed by the efflorescence of the salt, by the strong aluminous taste of the ashes, and by the appropriate chemical test of lixiviating an aliquot average portion of the mass, and seeing how much alum it will yield with a solution of sulphate of potassa, or chloride of potassium.

SPENCE, who lately sealed a patent for the manufacture of alum, offers the following as his method of calcination. He forms on the ground a number of air-channels, by laying parallel lines of common bricks at the distance of four inches apart, and placing others on these crosswise; thus the channel formed is about four inches square. The transverse bricks are placed on loosely, so as to allow the air to pass freely upwards; burning coals are laid on the channels, and a layer of the shale which is most bituminous, broken into small pieces; and as the combustion proceeds, other layers of the shale fragments, less bituminous than the preceding, are put on continuously, but not in too great a quantity. The thickness of each layer should be regulated by the briskness of the combustion, which should never go beyond a low red heat; but care must be exercised in maintaining the bed at this point, as a higher temperature would be apt to glaze or partially flux the materials, and render the alumina less soluble in acid. An examination of the following figure, exhibiting the heaps or mounds in various stages of progress, will show that a method similar to this is practised at Hurlet.

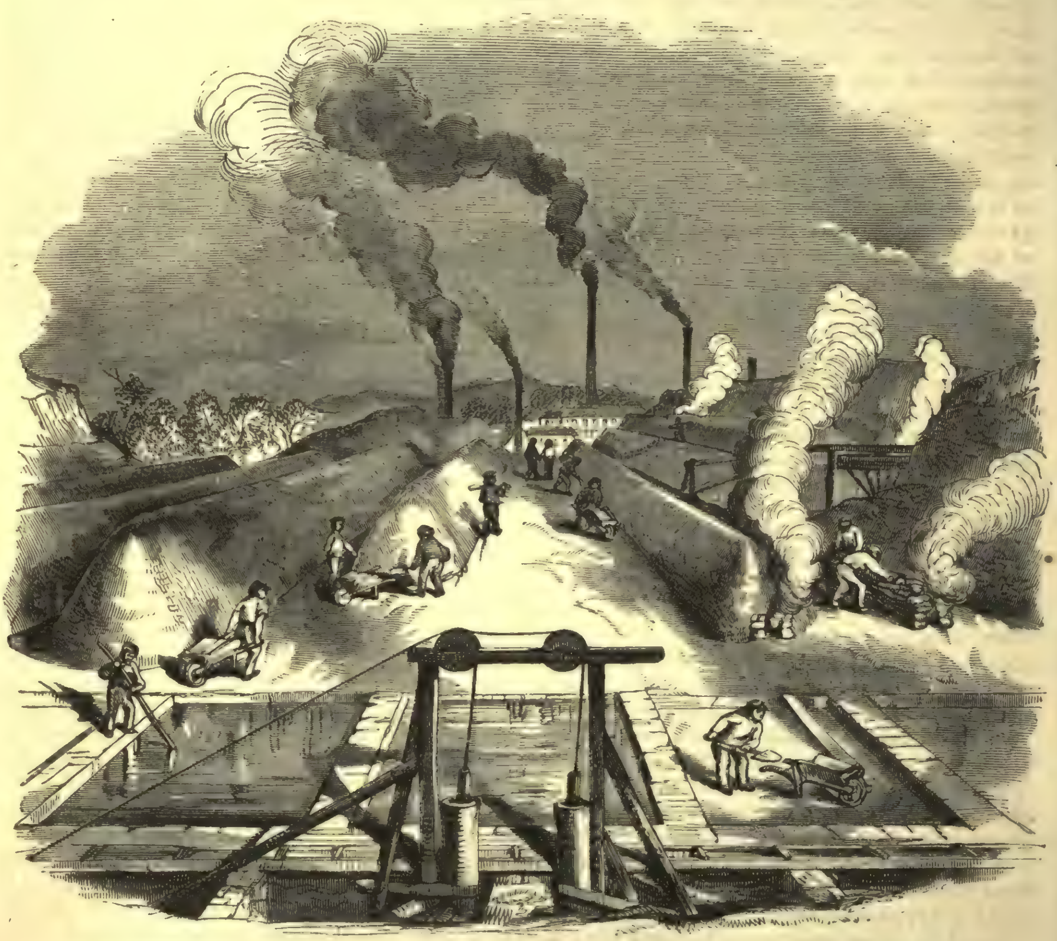
Shales destitute of bitumen, or prepared clays, may be calcined in the same way, by mixing with them small coals, or saw-dust; the heaps in either case may be made of any convenient dimensions, but the height most appropriate is four to five feet. The mass will burn out, and be cool enough for use in eight or ten days.

Lixiviation of the Roasted Ores.—This part of the operation for dissolving out the sulphate of alumina, and other soluble components, is one which requires much attention in regulating the proper amount of water which is required to extract the whole of the soluble bodies, without having a superabundance of unnecessary liquid to eliminate when the solutions are to be subsequently concentrated for crystallization, or precipitation. When an excess of water has been employed to exhaust the calcined shale, considerable time and labor are required for the evaporation of such liquors. If a manufacturer allows too much to be taken, he cannot compete with his neighbor who uses his best endeavors to cheapen the cost of production, especially in this age of rivalry. Hence, the chief study should be to employ only as much water as will effectually or nearly exhaust the ore of its soluble saline ingredients. Vessels for the lixiviation are either wooden cisterns lined with sheet-lead, or cisterns made of stone; the latter are more durable, but more expensive. The tanks, or lixiviating vessels, are placed in England and France at different levels, for the purpose of facilitating the exhaustion of the material in them, while in Scotland they are constructed upon the same plane. The form usually given to these vessels is that of a square or oblong.

When the exhaustion of the ustulated shale is effected by the first of these arrangements, as at Whitby, a wooden or iron sluice carries the lie from the series of tanks to a large cistern to be again returned upon the upper troughs, recharged with fresh portions of the burned ore, in order to bring it to the proper degree of strength, when it is drawn off to be concentrated by heat. Water is let into the upper troughs through several inlets, till it covers the burned material to the depth of one or two inches. After six to twelve hours, according to the facility with which the sulphates are extracted, the liquor from this tank is drawn off at the openings at the bottom into the cistern next beneath it, where it is suffered to remain for an equal length of time before it is run into the clarifying vessel, whence it is conducted to the pans for evaporation. No more than half the water employed in the first washing can be drawn off, as nearly half is retained by the shale; and, in consequence of this, only half the quantity of water used in the first is added to make the second lie, which, after twelve hours, is drawn off into the lower cistern, like the preceding, and a third quantity of water is poured on in order to extract the whole of the soluble ingredients. This third washing being of a low strength, is pumped up to form the first watering of fresh quantities of the material, to bring it to the desired strength for evaporating, which should be from 1·113 to 1·157.

At the Hurlet and Campsie Works, near Glasgow, the process pursued is the following:—After the ore is calcined, it is wheeled from the ridges into large stone cisterns, called *steeps*, occupying the same level —see Fig. 87. The steeps are furnished with false bottoms formed of planks, which rest on transverse beams, and the roasted shale is laid on the planks till it is about eighteen inches above the bottom. Water, or a weak lie from a previous operation, is poured upon the bed of adusted ore till it is completely covered over, and afterwards allowed to remain in contact with it for about eight hours. It generally remains over the night. A plug at the bottom of the vat is then opened, and the solution, which should have a specific gravity of about 20° Twaddle, or 1·100, is drawn off into the *settler*, or supply cistern, where it is allowed to remain at rest, in order that any matters held mechanically may subside. A second wash, of a weaker liquor than that employed in the first operation, is then added, and left in contact with the partly-exhausted shale as long as in the first instance, after which it is drawn off to the cistern as before; the same operation is repeated a third time if necessary, till the liquid becomes below 12° Twaddle in strength, after which it is not deemed economical to evaporate for alum, but retain the several washings for use in exhausting fresh quantities of ore. The last washings of the steep are made with water, and the strongest of the several resulting weak liquors from each steep is used the first in exhausting a fresh one. After the ore is deprived of its soluble ingredients, it is either removed to the waste heap, or returned to the calcining ridges, where it is intermixed with the fresh ore for the purpose of checking a too rapid combustion, when such is apt to take place.

Fig. 87.



At Valmunster, in the department of the Moselle, the tanks are constructed of burned stones and clay, and each has a capacity of 1728 cubic feet—1380 cubic feet Rhenish. At the bottom, at certain distances from each other, beams are arranged, upon which a layer of straw and brushwood is laid, and upon this the false bottom of boards is placed. This arrangement forms the filtering apparatus, from which the lie flows through apertures at the sides. Each cistern requires 1280 cubic feet of water for the lixiviation. Lie is first poured upon the ore, of 20° B. = sp. gr. 1·157; when this has run off, it corresponds to 24° or 25° B., and is fit for boiling; a weaker lie of 15° B. = sp. gr. 1·113, and subsequently others of 10° B., = sp. gr. 1·072, and the weakest, of 5° B., = sp. gr. 1·034, then follow; and lastly, the whole is washed out with pure water. All the lies that fall short of 24° or 25° B., are poured upon more or less exhausted ores, according to their strength. By arranging these cisterns upon terraces, the one above the other, the lie can easily be drawn from the upper into the lower cisterns, until it has acquired the proper strength. The solution is then called crude liquor, and is preserved in large walled tanks, ready for further operations.

The density of the liquors is determined by a specific gravity bottle, peculiar to the alum manufacturers; it is capable of containing eighty pennyweights of water at the ordinary temperature, and when this bottle is filled with the alum liquor and weighed, the excess of weight is denominated the strength in pennyweights; thus, if a liquor should weigh ninety pennyweights, it would be put as one of ten pennyweights, or simply liquor of 90. A simpler method is the use of the hydrometer, for determining the amount of ingredients dissolved, and this even in the pennyweights of the alum-maker; thus, dividing the indications of Twaddle's hydrometer by 2·5, gives the alum-maker's strength in pennyweights, without the trouble of weighing.

According to SCANLAN, eight different liquors are met with in the alum-works on the Yorkshire coast.

1. *Raw liquor.*—The calcined alum shale is steeped in water till the liquor has acquired a specific gravity of nine or ten pennyweights, according to the language of the alum-maker.

2. *Clarified liquor.*—The raw liquor is brought to the boiling point in leaden pans, and suffered to stand in a cistern till it has become clear; it is then called clarified liquor. Its gravity is raised to ten or eleven pennyweights.

3. *Concentrated liquor.*—Clarified liquor is boiled down to about twenty pennyweights. This is kept merely as a test of the comparative value of the potassa salts used by the alum-maker.

4. *Alum-mother liquor.*—The alum pans are fed with clarified liquor, which is boiled down to about twenty-five or thirty pennyweights, when a proper quantity of potassa salt in solution is mixed with it, and the whole run into coolers to crystallize. The liquor pumped from these rough crystals is called *alum-mothers.*

5. *Salt-mothers.*—The alum-mothers are boiled down to a crystallizing point, and afford a crop of *rough Epsom*, which is a sulphate of magnesia and protoxide of iron.

6 and 7. *Alum-washings.*—The rough crystals of alum—No. 4—are washed twice with water, the first washing being about four pennyweights, the second about two and a half, the difference in gravity being due to mother-liquor clinging to the crystals.

8. *Tun-liquor.*—The washed crystals are now dissolved in boiling water, and run into the roching-tuns —wooden vessels lined with lead—to crystallize. The mother-liquor of the *roch-alum* is called *tun-liquor;* it is of course not quite so pure as a solution of roch-alum in water.

With reference to the exhausted residues, two cases may occur: they have either been rendered perfectly porous by the roasting and decomposition, in which case they will have been completely exhausted, and may be thrown away unless they can be used for covering fresh heaps; or they still contain portions of undecomposed ore, and may then be subjected to a second exposure—as at Buchsweiler, in Elsace—either by themselves or mixed with fresh ore.

The process in many other alum-works, where the ores do not require roasting, is essentially the same as that described above. The lixiviation, however, is then carried on with the heaps themselves, and during the process of decomposition; they are erected for this purpose either upon flat wooden boxes, termed Bühnen, or upon a foundation composed of brickwork, or clay, which is completely impervious to the liquor, and where the water which is pumped from time to time upon the heap collects, and is thence conducted to the crude liquor cisterns. The soluble salts are thus removed at certain periods, as they are produced during decomposition. The strength of the crude liquor in the cisterns must be regulated by the respective prices of labor and fuel, weak liquor requiring more of the latter, and strong liquor more labor; it is never advisable, however, to concentrate the liquor to that degree at which it would be saturated with the crystallizable salts, such as green vitriol and sulphate of magnesia, as these would crystallize with the slightest amount of evaporation or rise of temperature before it is desirable they should do so. In general, the density indicated by 20° B., = sp. gr. 1·157, is not exceeded. SIMON found the crude liquor from Gleissen, in Newmark, to contain the following ingredients:—

Sulphate of alumina,............	11·085	= 29·678
Sulphate of iron,................	9·773	
Sulphate of soda,................	2·035	
Sulphate of magnesia,...........	1·754	
Sulphate of manganese,..........	0·174	
Sulphate of potassa,.............	0·095	
Sulphate of lime,................	0·120	
Sesquichloride of iron,..........	1·872	
Chloride of magnesium,..........	0·334	
Sesquichloride of aluminum,......	0·419	
Sulphuric acid,..................	0·563	
Hydrochloric acid,..............	1·454	
Water,..............................		70·322
		100·000

These constituents are always accompanied by a certain quantity of ready-formed alum, which may be potassa, or ammonia alum, or both, when a red heat has not been employed in the manufacture; but if a high temperature be applied, it decomposes the ammonia alum, leaving only alumina. To the production of the potassa alum, the alkali naturally contained in the ores contributes, and still more that which exists in the ash of the wood used as fuel; the production of ammonia is attributable to the nitrogen contained in the coal. During the time that the crude lie is clarifying in the large vats, a chemical decomposition ensues by the action of the air upon protosulphate of iron, which is not prevented by the state of solution of the salt.

10 Eqs. of sulphate of iron, $Fe\,O, S\,O_3 = Fe_{10} + O_{10} + 10\,S\,O_3$
absorb from the air 5 eqs. of oxygen, $= \quad O_5$

producing .... $Fe_{10} + O_{15} + 10\,S\,O_3$

Which consists of a basic salt that precipitates,.................... $= Fe_4 + O_6 + S\,O_3$
and 3 eqs. of sesquisulphate of iron which remain in solution,... $= Fe_6 + O_9 + 9\,S\,O_3$

$Fe_{10} + O_{15} + 10\,S\,O_3$.

In the foregoing analysis, this acid salt has probably been overlooked, or its constituents have been appropriated in some other manner; in the high state of dilution of the crude lie, however, nearly the whole of the oxide of iron is precipitated, and a very small portion remains in solution. This behavior is turned to account by mixing the crude liquor with the mud obtained in a subsequent operation; this mud is a kind of basic alum, that is soluble and deficient in a certain quantity of sulphuric acid to make it neutral alum, but which is supplied at the expense of the acid sesquisulphate of iron, or of the free sulphuric acid. The basic sesquisalt of iron is called in German *vitriolschmand*, and is collected from time to time from the bottom of the cisterns, and heated to redness; it then parts with its acid, and the peroxide remains, which is used as a red pigment.

Boiling the Crude Lie.—The further treatment of the lie depends upon the quantity of green vitriol which it contains, and in most cases there is quite as much or more of this salt than of alum. When this happens the lie is used for the production of both salts, and alum and copperas works are generally carried on conjointly. The process of separating the two salts by crystallization varies much in different manufactories.

When the crude lie is very much charged with the iron salt, it is evaporated in pans, into which old iron is thrown. The sesqui-compound formed by the action of the air is thereby partly precipitated as a basic *salt*, with the liberation of sulphuric acid which converts a part of the iron into sulphate, setting free hydrogen gas; the latter reduces the precipitated sesquisulphate of iron to protosulphate, and *prevents* its further oxidation during the evaporation. In order to afford more points of attachment for the crystals, and facilitate their removal, the workmen are in the habit of hanging peeled sticks and branches in the solution. The mother lie contains the whole of the sulphate of alumina, which is separated in a manner to be subsequently described.

In other places—as at Reschwitz, near Saalfield, at Schwemmsal—the greater portion of the water is removed by graduation, as in the salt-works, when, in consequence of the increased action of the air, a considerable portion of the green vitriol is decomposed, and much basic sulphate of iron, mixed with gypsum, is left as an incrustation upon the thorns. The graduated lie then yields green vitriol on evaporation, and a mother liquor containing the alum.

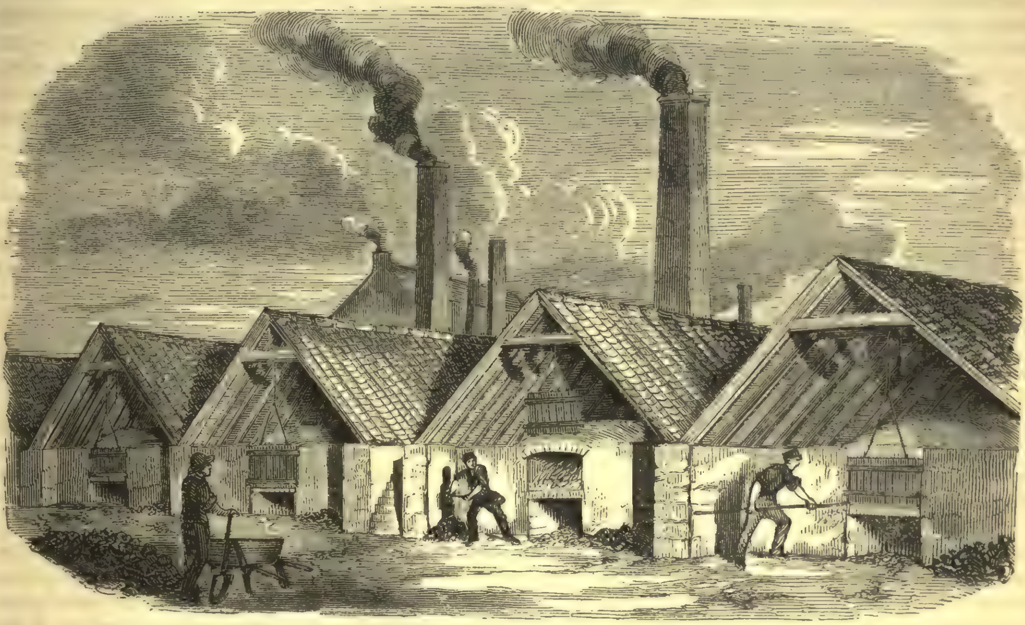
Another process consists in separating the copperas, not by cooling the saturated solution, but by simple evaporation, or abstraction of water, as in the soccage of common salt—for instance, at Buschweiler. When evaporation has been carried on for some time, and the loss of water and the strength of the lie have reached a certain degree, a point of saturation is attained—when the specific gravity is from 1·35 to 1·37, or 38° to 40° B.—at which the remaining water is just sufficient to retain the copperas in solution. The evaporation of every additional quantity of water then causes the precipitation of a portion of copperas, and a sediment, consisting of very small anhydrous or slightly hydrated crystals, is rapidly deposited. In the meantime, the evaporated water is constantly replaced by fresh liquor. It is obvious that, upon this plan, in which the liquor is always saturated, the quantity of dissolved copperas cannot accumulate in the pan, whilst the amount of the other soluble salt—sulphate of alumina—must increase synchronously with the deposition of the former until the liquid is saturated with it—a stage which is carefully attended to by observing if the hydrometer sinks to the same degree, in order that the other salts with which it will then be saturated may not precipitate with the copperas. On the one hand, the precipitated copperas is removed and purified by recrystallization, when its water of crystallization is raised to seven equivalents, and on the other a mother liquor remains, saturated with sulphate of alumina, for the production of alum.

When, on the contrary, the copperas is not in excess, the process is reversed, and begins with the production of alum from the crude liquor. For this purpose the lie is pumped at once from the crude liquor cisterns, in which it has been clarified, into the evaporating pans to be brought to the proper degree of concentration. If the pans are composed of tinned iron, they will be corroded by the sulphate of alumina and the lie, with the evolution of hydrogen and the precipitation of basic sulphate of alumina; this action, which is similar to that of an acid, is not prevented by the addition of the basic mud before mentioned. The sediment frequently gets burnt on the bottom, and causes difficulty and damage, particularly when cast-iron or leaden pans are employed, which are not otherwise affected; but the former of which are brittle, and the latter too easily melted by the heat. To prevent this burning, metal evaporating pans are now almost universally discarded, and the flame is carried over the surface of the liquid instead of below the pan. When, however, the liquors contain sulphate of magnesia, surface evaporation will not be so available as evaporation carried on in leaden pans heated from below, for when the concentration has proceeded to a certain extent, the magnesian and other salts form a crust on the surface of the liquid which protects it from the heated air passing over it.

At each of the Hurlet works there are six or seven evaporating basins, protected from the cooling influence of the atmosphere and rains by a shed-roofing, as represented in Fig. 88. These are long cisterns of brickwork, well cemented together, and arched over with the like materials; they have a length of sixty feet, and a breadth of six, with a depth of about four; they are capable of evaporating about four thousand five hundred to five thousand gallons in twenty-four hours. The cisterns are heated by a furnace, which is placed at one end, and on a level almost with the surface of the liquid when the boiler is full, as has been already described; a powerful chimney at the opposite end of the boiler creates a strong draught, that sweeps the flame and heat from the fire over the surface of the liquor, producing a very high temperature, and rapid evaporation takes place. Fig. 89 represents a longitudinal section of one of these evaporating cisterns.

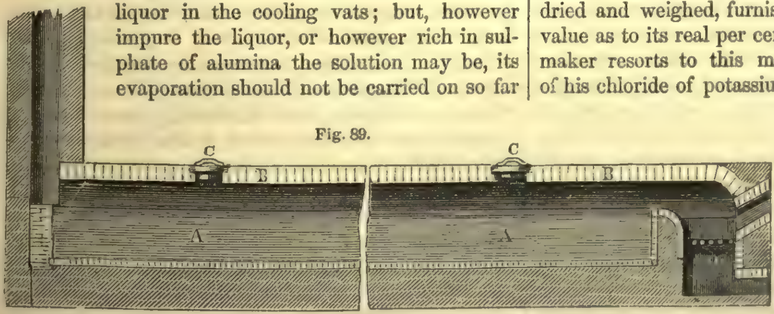
The liquor is placed in the basin, A A, the walls of which are made of brick, placed upright, and well cemented with mortar composed of lime and lixiviated alum-shale waste. In order that the current of air passing through the fire at D, may not carry any appreciable quantity of the ashes into the liquor, in course of evaporation, the fire bars are fixed at a low level; the flame passes below the flat arch, B B, to the chimney. This arch contains apertures, C C, adapted for observing the interior of the different parts. Fresh liquors, or the mother liquors from a previous operation, are introduced through the openings, C C, as the water is evaporated from the contents of the furnace, until the solution acquires a density of about 1·40, which is the most suitable state of concentration for producing the flour, or meal, in the next operation.

Fig. 88.



To economise fuel, the furnace is very long, and the fire communicates with an evaporating pan, so that, in either case, the whole heating power may be made available, as far as practicable. The draught of the furnace insures, in the simplest manner, a constant current of air over the liquid, which is favorable to evaporation by sweeping the vapors generated onwards to the chimney. During the evaporation of the liquor in the furnace, a copious sediment is thrown down, consisting of basic sulphate of iron—produced by the continuous decomposition of the copperas and neutral sesquisulphate of iron—gypsum, and other salts, of which it is necessary to clear the liquor in the cooling vats; but, however impure the liquor, or however rich in sulphate of alumina the solution may be, its evaporation should not be carried on so far as to cause a deposition of salt upon cooling; the ingredients must be entirely held in the clear solution, even after cooling the liquor in the vats appropriated to the production of the alum flour.

Fig. 89.



In the forementioned factories, the furnaces are fired incessantly for eight days, and the boiler is replenished with liquor from the supply cistern till the eve of the eighth day, when a charge of mother liquor is run in which deposits no sedimentary matter on boiling, like the fresh liquor; this is boiled down till it has the proper degree of strength, and then allowed to settle for twelve hours. After adding the mother liquor, it is customary to find the strength of the solution. This is done by taking out a known quantity of it, and concentrating it to the proper strength with chloride of potassium, allowing the solution to cool, and, after twenty-four hours, the crystals produced, when washed with a little cold water, dried and weighed, furnish an approximate test of the value as to its real per centage of alumina. The alum-maker resorts to this method for testing the quality of his chloride of potassium; but in this case he has a standard solution of aluminous sulphate. These experiments point out the quantity of alkaline chloride to be added per gallon of liquor.

At the Whitby alum-works, leaden pans are employed in consequence of the liquors from the calcined shale of this locality containing sulphate of magnesia, which renders surface evaporation as at Hurlet inapplicable, as already explained; the pans are ten feet long, four feet nine inches wide, two feet two inches deep at one end, and two feet eight inches at the other. In these lead pans the liquor is rapidly concentrated by a fire at one end, the flue of which runs along in parallel channels under a plate or course of brickwork on which the pans rest. Every morning the pans are emptied into a settling cistern of stone or lead. The specific gravity of the liquor should be about 1·40 to 1·50; this density must vary, however, with different kinds of lixivia, and according to the views of the manufacturer. For a liquor which consists of two parts of sulphate of alumina and one of sulphate of iron, a specific gravity of 1·25 may be sufficient; but for a solution of one part of sulphate of alumina and two parts of sulphate of iron, which latter is to be abstracted by crystallization, a density of 1·40 is requisite

PREPARATION OF THE POWDER.—From the evaporating basins, the liquor is run into the flour or powder cisterns, in which the sulphate of alumina is combined with potassa or ammonia—the *flux* or *precipitating substance*—in such a manner as to effect the first purification of the alum. The alum is only very slightly soluble in *the cold* mixture of the liquor with the solution of the precipitating substance, and for this reason the greater portion of it separates in the form of minute crystals, or *flour*, from the solution; the agitating motion given to the liquor in the cisterns favors the formation of the crystals. To obtain the largest yield of flour, it is necessary to add the precipitating solution as strong as possible, which is done by dissolving it in the least quantity of boiling water. The proper amount of the precipitant should be determined, as near as possible, by a preliminary experiment on the small scale; but still these data, though they serve to give an idea of the quantity, do not correspond always with the extensive operations of the manufacturer; so that even when previous experiments are made, to ascertain the true quantity to be added, much caution is necessary when operating on the whole bulk of mother liquor, as an excess of the precipitant may often cause much future inconvenience and labor. The best precipitating substances are potassa or ammoniacal salts, as they form alums which are very insoluble in cold water; only 9·25 parts of the potassa alum, and 9·16 parts of the ammonia alum being dissolved by a hundred parts of water at 50° Fahr. Soda salts are very disadvantageous precipitating agents in the formation of alum, on account of the great solubility of the resulting compound, forty-six parts of which are dissolved by a hundred of water at 50° Fahr., and, therefore, they are seldom used.

In the event of potassa salts being employed, preference is given to the chloride of potassium or sulphate of potassa; of the latter, 50·9 parts are required to precipitate one hundred parts of sulphate of alumina, from which results three hundred and thirty-four parts of crystallized alum. The preceding enumerated tests, however, will not answer in the factory, because the mother liquor is indefinite as to the amount of impurities which accompany the aluminous sulphate. To show the nature of this more clearly, let it be supposed that the mother liquor is saturated with sulphate of iron and sesquisulphate of alumina, and that its temperature is 50° Fahr. In this case, it will contain, for every

100· parts of water,
33·2 parts of anhydrous protosulphate of iron, and
33·5 parts of anhydrous sesquisulphate of alumina.

To precipitate these products, 17·1 parts of neutral sulphate of potassa are required, for the solution of which, sixty-six parts of boiling water will be necessary.

On mixing this solution with the lie, ninety-six parts of alum will be produced, together with the accumulated water of the lie and precipitant, which, collectively, will amount to one hundred and sixty-six parts. Of the ninety-six parts of alum formed, only sixteen can remain in solution after the liquid has cooled to the primary temperature of 50° Fahr.; therefore, eighty parts will separate in the crystallized state; but, in practice, this quantity diminishes according to the less saturated state of the lie. Since chloride of potassium is more soluble in boiling water than the sulphate of potassa, it is preferable for precipitating the alum flour; the chloride is soluble in two parts of boiling, and in three parts of cold water, and hence the mixture may be made in the cold.

In the instance cited above, the 33·5 parts of sulphate of alumina would require 14·5 parts of chloride of potassium for precipitation, which would be taken up by 26·2 parts of boiling water, and produce 96·5 parts of alum.

The mixture being made, and the precipitate subsided, twelve parts of the alum would be held in solution, so that only 84·5 parts of flour are thrown down in the solid form. If the same quantity of the chloride of potassium be dissolved in cold water, forty-six parts, at 50° Fahr., will be required, which, when added to the 23·5 parts of sulphate of alumina in solution, will yield eighty-four parts of alum as a precipitate, while 13·8 remain dissolved: in both cases, the difference is immaterial whether the precipitant be dissolved in hot or cold water.

Another precipitant which is used with much advantage, on account of its great solubility, is sulphate of ammonia; it is soluble in two parts of water, but the alum obtained when the sesquisulphate of alumina is precipitated with it, is less than when the potassa salts are employed, in the proportion of 100 : 95·6. The reason of this is, that the atomic weights of these two bodies differ, the hydrate of ammonia being 26, while the potassa is 47.

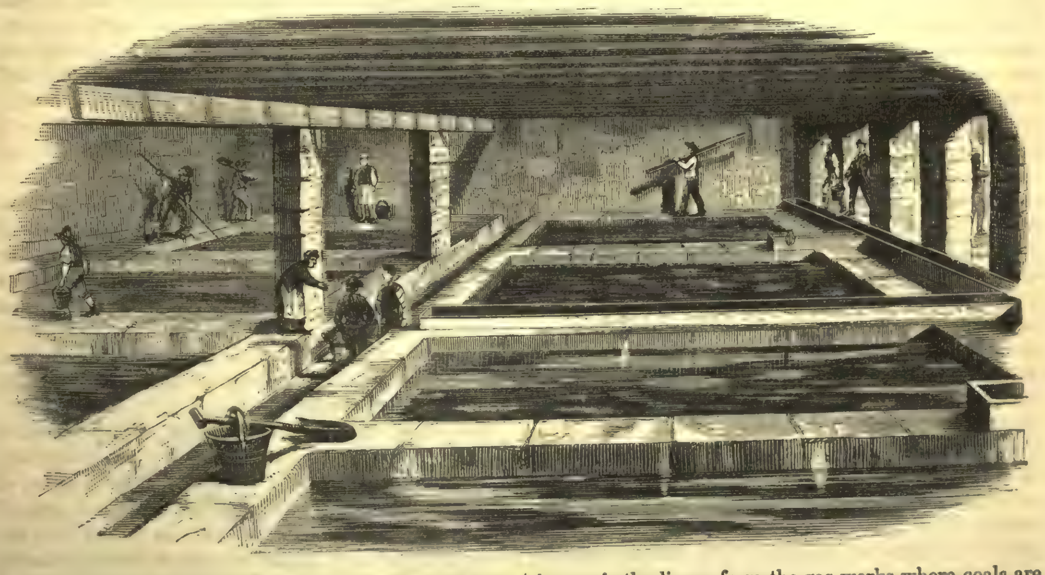
To recur to the foregoing example, the 33·5 parts of sulphate of alumina will take 15·8 parts of sulphate of ammonia to form with them 87·7 parts of alum, of which 77 parts are precipitated, and only 10·6 retained in the solution; thus, the disadvantage arising from the lesser equivalent of ammonia-alum is counterbalanced by the greater solubility of the ammoniacal salt as a precipitating agent.

The sulphate of potassa—for the use of alum-makers—is obtained as a secondary product in the manufacture of nitric acid, and in the purification of potassa, and the crude carbonate of that alkali: thus produced, it is a bisulphate of potassa, the composition of which is expressed by the symbols HO, SO_3, KO, SO_3, and cannot be employed as such till the excess of acid is neutralized by fresh additions of the caustic or carbonated alkali to form a neutral sulphate of the composition, KO, SO_3.

In no other case can the caustic alkali, or carbonate, be employed in the preparation of the alum flour, for if no free acid be present to unite with it when added, it would invariably throw down a basic double sulphate of alumina and potassa, which is insoluble in water, though redissolved by a further addition of bisulphate of potassa. A greater or less quantity of this compound is always formed during the evaporation of the liquors, in consequence of the iron present abstracting some of the acid, but, as in the preceding, a slight addition of the bisulphate of potassa redissolves it.

Knapp recommends that the purification of crude potassa and its carbonates should be conducted on the same premises with the alum-works, for the purpose of turning to use the bisulphates and chloride formed in this operation as precipitants of the alum. With regard to the latter salt, he says it is of greater importance than the sulphate, inasmuch as it effects the decomposition of the sulphates of iron, giving rise to sulphate of potassa, and chlorides of iron, which are highly deliquescent salts, and from which the alum flour can be removed with greater ease and perfection than from the sulphates of this metal. But the decided advantage attending the use of the chloride, is when a sesquisulphate of iron is present in the lie, as this salt, in combination with sulphate of potassa, forms a difficultly soluble though not insoluble double salt—basic iron alum—which would precipitate in the form of a yellow powder, and contaminate the alum flour. As an excess of the chloride of potassium would convert the sulphate of alumina into chloride of aluminum, a result which would entail a loss, he recommends that the lie should be examined before each operation, with a view to determine the proper amount of chloride to be added, as it happens that the quantity required to precipitate the whole of the alumina as alum, seldom or never meets with sufficient sulphate of iron in the lie to be converted into sulphate of potassa. This examination is conducted as follows:—A saturated solution of the precipitating salt is taken and added from a burette, or other graduated vessel, to a measured quantity of the liquor, the mixture being briskly agitated at each addition; successive portions of the reagent are to be poured in as long as the flour thrown down increases in quantity, and when no further precipitation is observed, the number of measures is read off, which, for sufficient accuracy on the large scale, will stand for the amount of solution required to precipitate a certain amount of the liquor; by this means, the tedious process of weighing is avoided. If sulphate of potassa has been employed, from its difficult solubility in the cold it may precipitate during the cooling of the liquor, apparently increasing the bulk of the precipitate, and giving rise to an error in the calculation. To avoid this source of inaccuracy, it is best to employ, as the testing liquor, a saturated solution of sulphate of ammonia, which being very soluble, both in hot and cold water, no precipitation of this reagent can take place; one part of the ammoniacal salt is equivalent to 1·32 parts of sulphate of potassa, or 1·13 of chloride of potassium.

Fig. 90.



Chloride of potassium, for the use of the alum-maker, is obtained in large quantities from the waste liquor of the soap-works—soap-boiler's waste—from saltpetre refineries, and from the glass-houses. Wood ashes should never be used in the manufacture, on account of the lime which they invariably contain.

The most fruitful source of the ammoniacal reagent in use, is the liquor from the gas-works where coals are distilled; this is converted into sulphate of ammonia, either by the addition of sulphuric acid directly, or by the decomposition of sulphate of lime or iron, which has the effect of converting the ammonia into sulphate, as will be subsequently described. The crude ammoniacal liquor obtained from the manufacture of chloride of ammonium, by the destructive distillation of animal matters, may be employed with equal advantage for the same purpose.

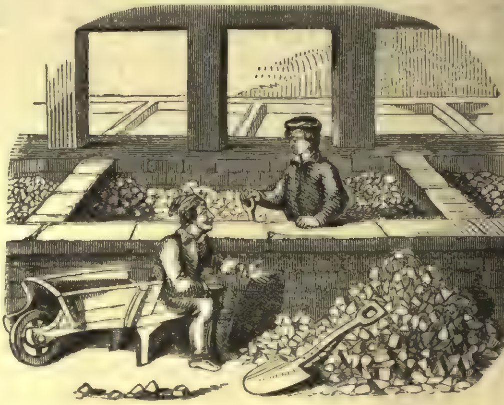
At Mr. KING's works, both at Campsie and Hurlet, only potassa-alum is fabricated, and the chloride of potassium is used as the precipitating agent. At Messrs. WILSON's factory, a large proportion of ammonia-alum is made, and most of the liquor from the gas-works in Glasgow, Paisley, and neighborhood is used for this purpose: when the works are in full operation, two thousand gallons of the gas liquor are consumed daily in yielding the ammonia, which is converted into sulphate with vitriol made on the premises.

Having prepared the aluminous liquor as already instructed, in the evaporating furnaces, and ascertained the content of salts per gallon, the concentrated solution of the precipitant being at hand, the crystalline flour is precipitated by gradually adding it to the aluminous solutions, the mixture being kept briskly agitated for some time, till the whole of the powder is thrown down. A slanting plane is fixed adjacent to the precipitating vessels, on which the workmen shovel the subsided powder, for the purpose of freeing it from the impure mother liquor of the vessel; the portion of lie adhering to the crystals drains off, and runs back to the mother liquor; still it does not wholly separate by this means, a small portion being mechanically retained by the mass of powder, which produces the brownish-yellow color of the crystals after the first draining. To remove the color, recourse is had to another process called *washing*. For this, it is sufficient to stir the powder with a small quantity of water in an appropriate tank or vat. The impurity mixed with the crystals is taken up by the water, as likewise a small portion of the alum, and when the substance has subsided, the liquor is drawn off by means of a siphon; two washings are found sufficient to separate all adhering foreign soluble bodies. The water employed in washing the flour should be of as low a temperature as possible, as the quantity of alum dissolved out is in proportion to the temperature of the water.

Fig. 90 is a view of the precipitating and crystallizing cisterns at one of the Hurlet works; they are constructed of stone, well adjusted and embedded in tempered clay, on a site contiguous to the evaporating furnaces. Having ascertained the quantity of sulphate of alumina per gallon in the concentrated liquor in those boilers, their whole bulk of lie is found by gaging, at the temperature of 60°. A corresponding amount of chloride of potassium, or sulphate of ammonia, is then weighed out and placed in one of the cisterns, after which the plug is removed from the boiler, and the liquor conducted along stoneware gutters to the coolers till it flows upon the heap of chloride. Sometimes the latter is gradually added to the liquor as it flows along in the gutters. Towards the end the mixture is well agitated to insure a complete solution of the alkaline salt and a uniform state of the liquor. In four or five days, when the plug is drawn out from the cistern and the mother liquor run off, the bottom and sides of the cooler are found lined with crystals of alum, generally some inches in thickness. This is called *first alum*, and is removed from the vessel to the draining stage, which is a raised platform in a sloping position, so that the mother liquor drains off from the heap, as shown in Fig. 91.

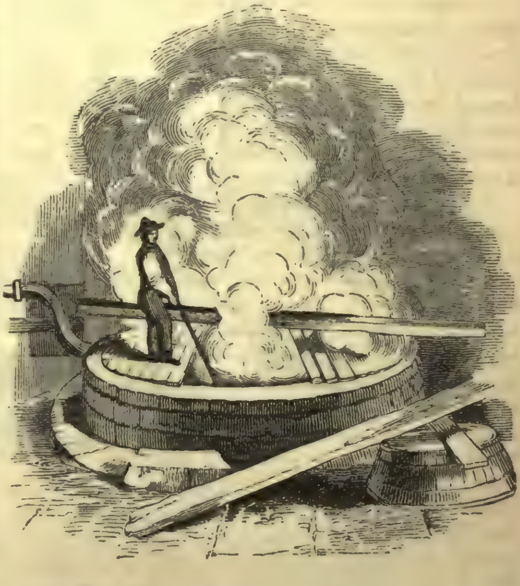
The first alum having been drained, is now washed to remove as much of the mother liquor from it as possible. For this purpose, tubs are filled with second alum mothers, or liquor which has been used in washing in a subsequent part of the process; and the alum, placed in wooden sieves, is rinsed in this liquor, and thrown on the stage.

Fig. 91.



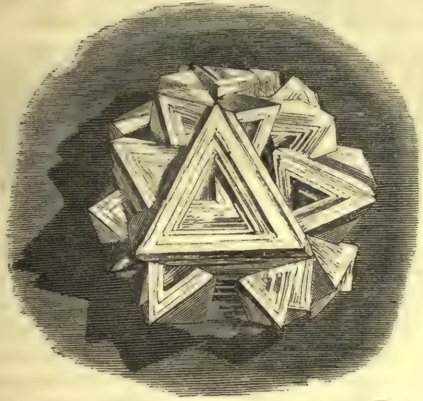
The second alum boiler, which is a deep stone cistern covered with wood—Fig. 92—is then prepared, by running in a quantity of liquor which had been previously used in washing the second alum; steam is next introduced, till the menstruum has nearly attained its boiling point, when the washed and drained crystals are thrown in, and constant agitation kept up. This is continued till as much alum has been added as will increase the specific gravity to 60° Twaddle, and the temperature is raised as much as possible by the steam, which is then

Fig. 92.



shut off, and the boiler being closely covered up, the liquor is allowed to remain at rest for twelve hours, for all the impurities to settle; the plug is then removed, and the clear liquor runs off to the second alum coolers, which, like the preceding, are sunk stone cisterns. In these it remains for four or five days, when the sides and bottom are found lined with alum, now nearly white, to the thickness of eight or nine inches. The small cup-like clusters of second alum crystals, which form on the surface of the coolers at this stage of the process, and successively fall to the bottom, assume the beautiful appearance exhibited in Fig. 93. The mother lie, which should have a specific gravity of 26°, is removed, and used for washing up the first alum as already described; and the crystals, being broken up, are affused with pure water, and drained, previous to the finishing process.

Fig. 93.



Crystallization.—The powder or alum flour, of minute, or imperfect crystals, prepared as before mentioned, is very seldom sent to market as such, the consumers of the article preferring to use the salt in the form of large crystals; they satisfy themselves likewise, that it is less liable to be adulterated with any other impurities when in a well-defined crystalline state, than if it were amorphous.

Crystallization of the alum flour, to answer the demand of the manufacturers who require it, and for sale to the public, is effected by dissolving it in as little boiling water as possible, and when no more of the substance is taken up, the saturated solution is run into crystallizing vessels, which are denominated *roching casks*, or *growing vessels*. Steam is better adapted than water for the purpose of dissolving the flour. A large wooden vessel, lined with sheet-lead, is provided for this purpose, and in the interior the powder is sustained occasionally on perforated shelves, so that the steam which issues from the pipe that enters at the bottom may have more extensive contact with it, and thus dissolve it more readily. As the steam penetrates through the several diaphragms bearing the powder, part is dissolved; that which is liquefied in the upper ones is concentrated by the hot steam as it falls down to the bottom of the vessel, and being hot, it is at once run into the vessels for crystallization.

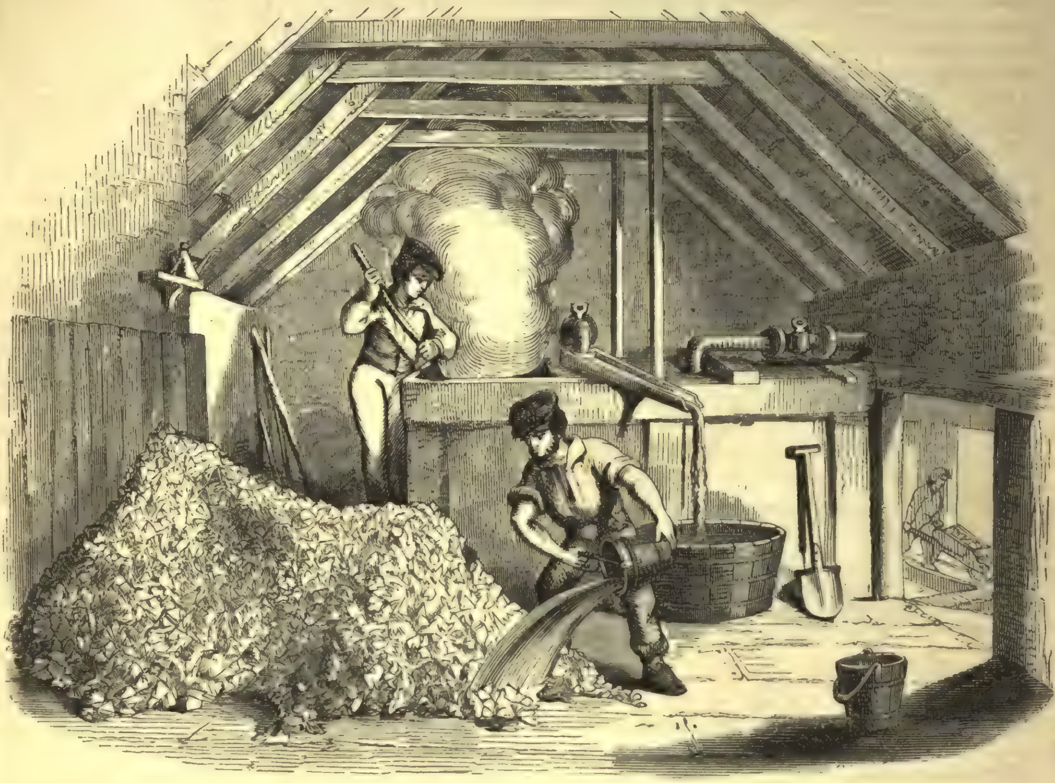
Fig. 94 is a drawing representing the roching-pan which is usually found in the extensive alum factories of England and Scotland; it works on the above principle, and is therefore advantageous in rendering a subsequent evaporation unnecessary. It is a large covered leaden cistern, into which steam is forced, and the alum is shovelled in to meet it; a solution takes place rapidly, without any addition of water. The temperature of this solution having reached 96°, the heat is raised as high as possible, generally to 224° Fahr., and the steam being shut off, the pan is closely covered up, and allowed to remain at rest for four or five hours, or till the temperature has fallen to about 200° Fahr. The water which has been used for washing the crystals, is again taken for washing the first alum, as above.

At Valmunster, this operation is carried on in vessels constructed as follows:—The wooden troughs are lined with lead in the ordinary way, but are closed by a lid in which are two openings; one of the openings receives the steam-pipe, and the other a wide leaden funnel. The sides of the funnel are perforated with small holes, three hundred of which are inserted in every square foot of surface. In this funnel the alum flour is placed, and the steam injected through the pipe, in seeking to escape through the apertures in the funnel, dissolves the powder; the solution trickles to the bottom of the vessel at a temperature of 212°. At the termination of the process, a modicum of undissolved basic alum is left in the funnel, which is added to some concentrated liquor ready for precipitation by sulphate of potassa, and is redissolved as before stated. During the time the flour is dissolving in the roching vessel, the crystallizers are being prepared, and the aluminous solution, of a density about 1·485 to 1·515, is run into them by appropriate means.

These crystallizers are large wooden casks, five to eight feet high, three or four feet in diameter at the top, and tapering in a somewhat conical form towards the bottom. The staves of these casks are very strong, nicely adjusted, lined with sheet-lead, and held together by means of strong iron hoops, which are hammered on when required for use, and may be as easily removed.

Fig. 95 is a view of these casks arranged in the crystallizing shed, over each of which a spout is furnished for filling them with the liquor. Some of the casks are represented as on the point of being charged, while in others the crystallization is completed, and from which the staves are being taken off. When the casks are charged, they are covered up, each with its own lid. Being allowed to remain for four or five days, according to the state of the weather, the hoops are loosened and the staves removed; a crust of alum is formed, which is sufficiently strong to resist the pressure of the interior liquor. In this state they are left for a fortnight, in order to allow the whole of the crystallizable salt to form. The workmen then pierce a few holes in the sides of the column with an axe, so that the mother liquor in the interior may flow out into the gutters in the stone floor, which conduct it into an appropriate cistern, whence it is pumped up to dissolve fresh quantities of the prepared alum flour, and recrystallized as indicated. When the roching casks are dismantled, and the alum of the upper part removed, there is invariably found at the bottom a considerable quantity of white slime mixed with small octahedral crystals of alum. A quantity of this slime, well washed, gave the following centesimal composition:—

Fig. 94.



	Per Cent.
Sulphuric acid,	39·40
Alumina,	31·80
Potassa,	10·03
Moisture,	16·70
Insoluble matter,	2·07
	100·00

On examining the insoluble portion, it was found to contain

	Per Cent.
Silica,	73·79
Alumina, with a trace of iron,	21·83
Lime,	3·49
Loss,	·89
	100·00

The mother liquor which remains after the separation of the alum, is composed of solutions of sesquisulphate and protosulphate of iron, chlorides of iron, sulphate of magnesia, and alkaline sulphates; and when soap-boiler's waste has been used as the precipitating agent, it contains, in addition to the foregoing, soda alum in moderate quantities: if bisulphate of potassa, saturated with wood ashes, has been employed, the liquor will contain some sulphuric acid, and other ingredients, in small proportions. By knowing the nature of the alum shale, or ore, in the first instance, from a chemical analysis, a good idea can be formed of the principal bodies remaining in the mother liquor, and the subsequent application of it to the formation of secondary products; for instance, if free acid should be detected in the lie, it may be employed to neutralize crude carbonate of ammonia from the gas-works, to procure sulphate of ammonia; or, if much iron be present in the acid liquor, a further addition of borings of iron,

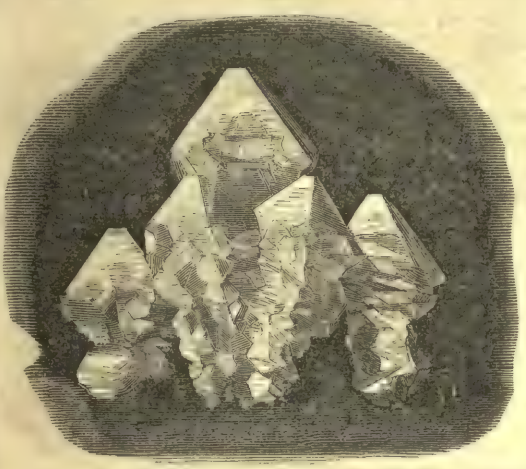
Fig. 95.

or old iron, is added, and in this way sulphate of iron for manufacturing purposes is formed. Should the mother liquor contain large quantities of the mixed chlorides of iron, it may be evaporated to dryness, and the dry mass heated to redness in a reverberatory furnace to drive off the hydrochloric acid, and thus sesquioxide of iron which may be used as a pigment is obtained.

Even sulphate of magnesia—Epsom salt—is manufactured from the mother liquors of the ores.

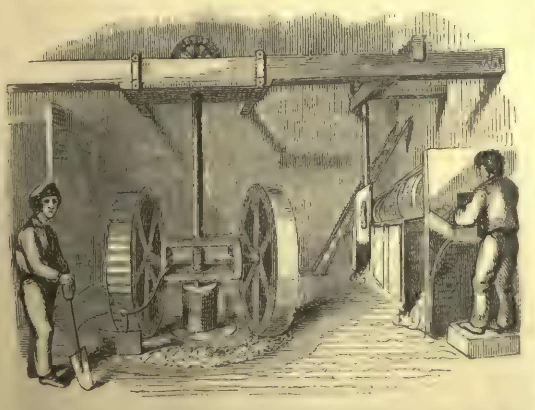
The mass of alum is cut into square blocks for market, when it will be found interiorly to consist of beautiful large octahedral crystals, similar to Fig. 96, which project from the sides and cover of the vessel.

Fig. 96.



For some purposes the alum is preferred in the form of a fine powder or flour, and in this state, therefore, a portion is prepared for the market. Fig. 97 is a sketch of the machinery usually employed at the alum-works for this purpose. The alum, reduced to coarse fragments, is crushed beneath a pair of ponderous wheels or rollers, of cast-iron, one of which is rough or fluted on the rim, and the other perfectly smooth. These traverse in a circle, and the alum is constantly pushed into the path of their revolution by two vertical revolving blades, one of which sweeps it inward, and the other outward. The grooved roller crushes the larger fragments before they are subjected to the action of the smooth surface of the other. When one charge is thus reduced to powder, it is shovelled out by an attendant to make room for a new supply; and the powder is passed by hand into a hollow cylindrical sieve, shown at the right hand of the figure. The lower portion, or belly of the cylinder, which lies in a slightly inclined position, consists of fine wire-gauze; the upper convexity is made of white-iron. This is surrounded by wooden hoops, to which are attached brushes that pass into the interior of the cylinder. An oscillating motion is given to the latter, and that portion of the alum powder which has been reduced to a state of sufficient fineness, is driven by the action of the brushes through the sieve, from which it falls in a beautiful white flour into a box below—the coarser particles passing onward to the other end of the cylinder, to be again subjected to the action of the crushing rollers. From one-tenth to one-eighth of the produce of the Scotch alum-works is sent to market in this form, in which it is easier of solution, and therefore more convenient for some of the numerous processes to which it is applied in the arts.

Fig. 97.



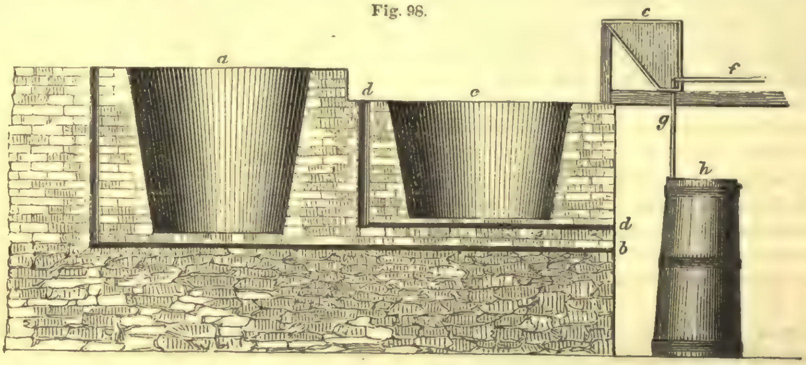
PRODUCTION OF ALUM FROM ROCKS CONTAINING ALUMINA.—Alum has been produced from various rocks of which alumina forms a constituent, by a process similar to that which naturally gives rise to this body in volcanic districts. The operation is confined to one or two isolated works on the Continent, and those are conducted in juxtaposition with metallurgic operations where sulphurous acid is in abundance. At Lintz, on the Rhine, where there is a spelter-work, and plenty of zincblende—sulphide of zinc—the sulphurous acid evolved during the roasting of the ore is conducted over the aluminous mineral moistened with water. Basalt and copper slate are the materials employed, and when these are exposed to the action of the gas, and sufficient moisture and air, decomposition ensues; sulphate of alumina, with sulphates of iron and copper, are formed, which are separated from the insoluble residue by steeping with water, and the subsequent treatment for obtaining the alum is on the same principle as those methods which have been already described. In such operations there is always a quantity of soda alum produced, on account of the presence of this alkali in the basaltic mineral. The soda alum is formed from the commencement, and the amount corresponds of course with that of the soda in the mineral, which in many basalt rocks is from five to six per cent.

ALUM FROM CLAY.—CHAPTAL and ALBAN, in France, pursued a different course for the preparation of alum from clay. Clay consists of basic silicate of alumina, or silicate of alumina with free alumina, $Al_2O_3\ 3\ SiO_2 + Al_2O_3\ 3\ HO$ (?), and by the action of sulphuric acid, sulphate of alumina is formed with separation of silicic acid. Plastic or pipe-clay answers the purpose best; but that the acid may more readily penetrate the mass, the clay is submitted to a previous calcination to increase its porosity, and more fully oxidise the iron which it may contain. Fresh clay, when employed, requires a considerably longer time than when it is calcined and pulverised previously to the addition of the acid; if it be found requisite, the ground material is sifted. Forty-five per cent. of the weight of the clay of sulphuric acid, of 45° B., is poured upon it in a cistern which is heated, by the superabundant caloric from the calcining furnace, to about 158° Fahr. Decomposition ensues, and the mass assumes a greater consistency from the liberation of silicic acid; in this state the contents of the cistern are removed to the open air, where they are allowed to remain for a space of some months, to allow of the complete disintegration of the clay by the acid. The mass is afterwards lixiviated, and the sulphate of alumina treated as in ordinary cases. Clay, with as little iron and lime as possible, should be selected. Some manufacturers employ large shallow troughs, lined with lead, and heated from below by flues, for the purpose of mixing the prepared clay with sulphuric acid, in which it is frequently turned over until the acid has combined with its alumina. In this part of the operation an improvement has been lately effected, which consists of distributing the clay upon a shallow circular trough, and permitting the proper quantity of acid to flow in several small jets from a cistern placed above, while a rouser, worked by machinery, mixes the clay and acid thoroughly. In this way a more speedy combination is effected, than in the forementioned method. After the termination of the action of the acid, the contents of the cistern are removed to the stone pit, *a*, Fig. 98, where they are treated with successive quantities of water, to extract the sesquisulphate of alumina. Each lie is siphoned off into the pipes, *b b*, which convey it to the evaporating pans, to be boiled down to the proper strength for precipitating with the alkaline salt. When this point is attained, the liquor is pumped up into the stone pit, *c*, which is similar to *a*, already described, and called the precipitating vat; here the appropriate addition of sulphate of potassa is made. On agitating the solution, the *alum powder* precipitates; this is allowed to subside, and the mother liquor is drawn off to the pipes, *d d*, by a siphon. If the mother liquor be not very impure, it is employed for a subsequent precipitation. The precipitated alum is washed in the cistern, *c*, with successive small portions of water, each liquor being drawn off repeatedly in the same way as the mother liquor.

When the powder is purified by repeated washings, it is ladled out into the funnel-shaped vessel, *e*, where it is very economically dissolved, by injecting steam upon it through the pipe, *f*, and the saturated solution of alum descends to the crystallizing frame, *h*, through the pipe, *g*.

The evaporation of the various liquors is conducted in boilers lined with lead, by means of convoluted steam pipes placed in the liquid. This plan of concentration of the liquid is found to be best adapted for such liquors, as well as being cheaper.—*Knapp.*

Fig. 98.



Mr. Taylor, of Bristol, proceeds in making alums from pipe-clay, by calcining it in the usual way, and then treating it with its own weight of sulphuric acid, of specific gravity 1·200, in a large tub, upon the bottom of which a steam-pipe is coiled for the purpose of heating the mixture to about 200° or 212° Fahr., and some furnace clinkers and pieces of pottery, or other matters, are also strewed upon it to facilitate the filtration of the solution of sulphate of alumina. After the mixture of clay and acid has been heated for twelve hours, the solution is drawn off through a pipe at the bottom of the tube to the precipitating vats at a density of 1·300.

From Felspar.—This mineral, which is a double silicate of alumina and potassa—$Al_2 O_3 3 Si O_2 + K O Si O_2$—is decomposed by sulphate of potassa in a reverberatory furnace, and then fused with carbonate of potassa to a glass; on treating this with boiling water, decomposition follows, a soluble silicate of potassa dissolves, while an insoluble double silicate remains. The insoluble portion, when treated with boiling sulphuric acid, is decomposed into alum, and silica separates. The alum is dissolved out by water, and the solution evaporated for crystallization; the soluble alkaline silicate may be turned to account by combining the silica with lime.

Turner was the first to carry out the proposition of Sprengel, of converting felspar into alum. A patent was granted to him in 1842 for his process, which he describes in his specification as follows:—If desirous of making potassa alum, the best substance to operate upon is a potassa felspar. This felspar is ground in a common edgestone mill, till the powder is like fine sand, a process which is much assisted by heating it to redness, and then plunging it in cold water; it is afterwards mixed with its own weight of sulphate of potassa, and placed in the upper part of the inclined bed of a reverberatory furnace, similar to the annexed, Fig. 99—known in the potteries as a *frit-furnace*—previously brought to a red heat. When the glass produced by the fusion of the powdered mineral and the alkaline sulphate has been observed to flow down to the bed of the furnace, there is added gradually, at the lower end of the furnace, as much carbonate of potassa as was previously used of sulphate. This operation of adding proportionate quantities of carbonate of potassa to the molten mass as it flows down into the lower part of the furnace, is continued till the *sack* of the furnace is quite full, the mineral and sulphate being introduced at the upper end: the glass is then fit for the next operation.

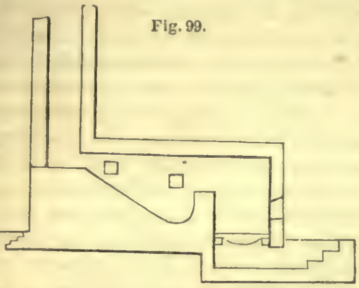


Fig. 99.

The compound might be prepared in a furnace with a flat bottom, from which it is separated with greater facility; in this case, however, no carbonate should be used till the whole of the sulphate has been observed to be decomposed, after which it is to be introduced, as in the preceding instance, and fused with the mass. On boiling the glass produced in this manner with water, the same quantity of potassa as was added to the felspar, and two-thirds of the silica contained in the mineral, are dissolved, while the remaining one-third of silica, and the alumina, and an equal quantity of potassa as the felspar originally contained, are left in the form of a light porous substance, similar in composition to elaolite, which is carefully separated from the solution, and washed well with water to withdraw silicate of potassa; next, the porous precipitate is put into a large leaden cistern or boiler, wherein it is acted upon with boiling dilute sulphuric acid, of specific gravity 1·20, which will contain sufficient water for the solution and crystallization of the alum formed by the decomposition of the elaolite. As a general rule, as much acid should be added in the diluted state as will contain one hundred and sixty pounds of dry acid to every two hundred and eighty-five pounds of felspar employed. If other minerals should be acted upon, a proportionate quantity of acid should likewise be used, that the solution of alum formed may not be impregnated with free sulphuric acid. To guard against the too great acidity of the solution, it is better not to add but one-fourth of the quantity of sulphuric acid to the elaolite formed in the first operation; part of the substance will remain undecomposed after the alum solution has been drawn off, but this may be acted upon by the whole of the remaining quantity of acid, and will be completely decomposed, and the liquor retained to act on a fresh batch. In the second operation, any free acid that had been left is neutralized, and a solution of alum from excess of acid is thus produced. The boiling menstruum, after the sediment subsides, is drawn into coolers, such as are generally used for crystallizing alum; here about four-fifths of the alum contained in the liquor will separate in crystals. From this mother liquor the residual alum is obtained by evaporating it to dryness; by this means the silica present in the solution is rendered insoluble, and the dry mass is acted upon either with water or a further quantity of mother liquor, and the solution evaporated to the crystallizing point as before.

Had soda salts been used in the above process, soda alum would be produced; but for this end albite is preferred, as it contains an excess of this alkali. The potassa or soda—as the case may be—which is extracted from the elaolite or nepheline—formed when soda is used—in the solution, is recovered by the following methods:—The strong solutions which are obtained, about the specific gravity of 1·20, are placed in any convenient vessel through which a stream of carbonic acid is transmitted; the carbonic acid is absorbed, and the solution assumes the appearance of a gelatinous mass from the separation of hydrated silicic acid; the liquid contains carbonate of soda or potassa.

On drying this mass in a furnace, which should never, under any circumstances, be allowed to rise to a red heat, the silica loses its water, and becomes insoluble; and by subsequent treatment of the dry residue with water, the alkali is dissolved out in the form of sesquicarbonate, which is obtained in the solid state by evaporation.

The second method, which is the simpler, is to filter the alkaline silicate through a bed of caustic lime, when it will be found that the lime has combined with the silica, and caustic alkaline lie passes through. An apparatus, similar to that of a soap-boiler for the preparation of his lies, may be used; and the alkali may be subsequently converted into carbonate, in the usual way of making soda ash.

With the exception of the high temperature required to decompose the felspar, TURNER'S process is very successful, but this was found to be a serious drawback when working on the large scale.

TELGHMANN has lately procured a patent for obtaining sulphate of potassa and chloride of potassium by acting on felspar, and by working on this principle in the manufacture of alum the impediment just mentioned might be overcome.

Alum may likewise be obtained by treating a mixture of two parts of felspar and three of fluorspar with sulphuric acid at a low red heat, until vapors of hydro-fluosilicic acid cease to be evolved. The decomposition of the fluorspar by the sulphuric acid causes the liberation of hydrofluoric acid, and this in turn decomposes the silicates, combining with their silicic acid to form the evolved hydro-fluosilicic acid, as is seen in the annexed equation—

$$\begin{array}{l} Al_2\,O_3\,3\,Si\,O_2 + K\,O\,Si\,O_2 + 12\,Ca\,F + 4\,H\,O\,S\,O_3 = \\ Al_2\,O_3\,3\,S\,O_3 + K\,O\,S\,O_3 + 12\,Ca\,O + 4\,H\,F,\,Si\,F_2. \end{array}$$

Sulphate of lime is formed in the first stage of the process; but this is subsequently decomposed, and the sulphuric acid transferred to the alkali and alumina, as these bodies are deprived of their silica.

The mass is lixiviated with water, and after the separation of some sulphate of lime, the solution is evaporated, and on cooling it deposits an abundant crop of nearly pure alum crystals.

Mr. **Wilson**, of Glasgow, secured a patent in 1849 for the manufacture of alum by a new process, the chief advantage of which is stated to consist in the manner of heating the liquids for digesting the shale, and in applying the mother liquors after precipitating or separating the alum, so as to make the sulphuric acid, either free or in combination with other bodies, available in subsequent operations.

The first part of the patent process is an improvement upon the prevailing mode of digesting the shale with sulphuric acid diluted with water or mother lie, the liquor being poured on in the cold, and heat communicated afterwards to the digesting vessels, either by steam or the application of fire. He first warms the mixture of sulphuric acid and water in a separate vessel, and runs it into the digesting tank containing the calcined shale, at a temperature between 150° and 200° Fahr., as is deemed necessary, and then maintains the heat at the proper degree, by conducting the waste caloric from the furnace of the heating vessel below, through flues under and around the digesters. The patentee alleges that, by this arrangement and method of operation, considerable saving of fuel is effected, and that there is a more perfect and uniform digestion than by the old system, wherein it was impossible to obtain a proper and efficient temperature throughout the mass of shale.

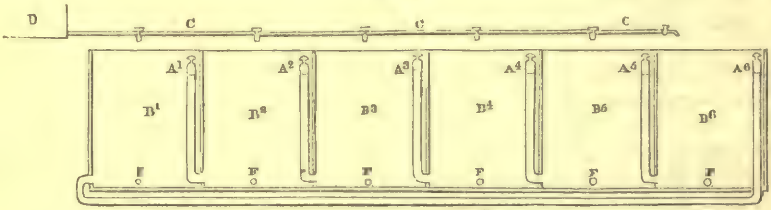
To prevent the loss of sulphuric acid, the ordinary method is varied in the following manner:—The strong mother liquors, left over after depositing the alum formed from the combination of the sulphate of alumina with the sulphate of ammonia, are not used again to dilute the acid, but are employed with fresh ammoniacal liquor from the gas-works, or elsewhere, to form sulphate of ammonia. He guards against the decomposition of the portion of alum which the mother liquor held in solution, by adding the ammoniacal liquor in such quantities, as that a slight portion of acid in the liquor is uncombined. A few trials would enable the operator to judge, by means of test papers, the proper point at which the neutralizing should be suspended.

When the solution of the mixture of sulphate of ammonia and alum, after filtration, or reposing to allow impurities to deposit, is sufficiently concentrated by evaporation, it is run in among the solution of sulphate of alumina from the digesters, and the alum which it contains is deposited with that of the fresh liquor.

Wilson also obtained a patent previous to the above, for manufacturing alum from the shale of the coal formation, which, however, scarcely differed from the usual method, excepting in the roasting of the ore. The plan, moreover, does not appear to have been successful.

Richardson, in 1850, sealed a patent for further improvements in the manufacture of alum, the leading parts of which are as follow:—In lixiviating the calcined shale for the purpose of obtaining the raw alum liquor, a series of pits, such as is seen in the annexed figure, is employed. Fig. 100 shows the manner of effecting the solution of the sulphate of alumina.

Fig. 100.



B^1 B^2 B^3, *et cætera*, are a series of pits, furnished with pipes, A^1 A^2 A^3, *et cætera*, for the purpose of conveying mother liquor from one to another, the pipes being stopped with taps or cocks, as seen in the figure. Water is run from the service tank, D, through the pipe, C, into the pit, B^6, till it flows over through the pipe, A^6, and passes through the pipe, E E, till it enters B^1, through which it rises till the pit is filled, exhausting the contents of the soluble ingredients in its ascent. When the liquor has stood for some days, a fresh supply of water is continued as before in B^6, by which the liquor in B^1 is forced over through A^1, the plug being removed into the pit, B^2, containing fresh calcined shale; the liquor ascends through the shale in this pit as in B^1, and when it has remained two or three days in contact with it, a fresh supply of water is allowed to flow into B^6, which forces the liquid contents of B^2 into the third tank, and the treatment repeated as long as the workman finds it necessary, to bring the liquor to 28° Twaddle, or such higher strength as is required; and when the proper degree of saturation is attained, the solution is drawn off by the stopcock, F. As soon as the shale in any of the pits is found to be exhausted, it is removed, and a fresh supply introduced, and the lixiviation proceeded with as before.

Of course, as the operation goes on week after week, it will become necessary to commence the supply of water from the service tank, D, to the different pits in succession, which may be done as above described, or by allowing it to run at once down the pipes, A A A, from the respective taps in the pipe, C. By these arrangements, the labor of pumping the liquor from one pit to the other will be saved, the process generally rendered more convenient, and the result will be a more perfect exhaustion of the shale.

Produce.—The great variation in the character and richness of the ores does not admit of even a proximate relation being established between the quantities employed, and the amounts of alum produced in different works. At Valmunster, from seventeen million three hundred thousand pounds weight of alum shale, four hundred thousand hundred-weight of alum, or 2·3 per cent., are obtained, for the production of which one hundred thousand pounds of sulphate of potassa are required, and one million four hundred thousand pounds of coal consumed.

The slate at Liege yields two per cent. of alum, and that from other localities only from one to one-half per cent.—*Knapp.*

PROPERTIES OF ALUM.—Potassa alum, when submitted to a heat of about 570° Fahr., fuses in its water of crystallization; the water being expelled during the fusion, the melted mass presents a pulverable white porous appearance, and is converted into anhydrous or burnt alum, which redissolves with difficulty in water; nevertheless, it absorbs its water of crystallization slowly from the air. At a red heat, the sulphuric acid of the sulphate of alumina is partly expelled in an anhydrous state, and partly as sulphurous acid and oxygen, while sulphate of potassa and alumina compose the residuum. Ammonia alum behaves in a similar way, but, after being heated to redness, only pure alumina remains; both varieties react acid on litmus paper. The composition of artificial alums has been made the subject of a chemical investigation by several chemists; a few of the results are given in the following analyses:—

POTASSA ALUM.

	Thomson.	Thenard.	Vauquelin.	Graham.	Theory.
Potassa,	9·86	10·02	10·40	—	9·95
Alumina,	11·09	12·53	10·50	54.11	10·83
Sulphuric acid,	32·85	26·04	30·52	—	33·71
Water,	46·20	51·41	48·58	45·89	45·51
	100·00	100·00	100·00	100·00	100·00

SODA ALUM.

	Wellner.	Ure.	Zellner.	Graham.	Theory.
Soda,	6·29	6·48	6·67	—	6·80
Alumina,	10·19	10·75	11·00	52·53	11·21
Sulphuric acid,	35·10	34·00	34·32	—	34·89
Water,	48·22	49·00	48·01	47·47	47·10
	99·80	100·23	100·00	100·00	100·00

AMMONIA ALUM.

	Riffault.	Forchhammer.	Theoretical.
Ammonia,	—	—	3·75
Alumina,	11·906	11·24	11·34
Sulphuric acid,	36·042	35·90	35·29
Water,	—	—	49·62
			100·00

CHINESE ALUM RECENTLY IMPORTED INTO THIS COUNTRY.

	Richardson.
Sulphuric acid,	34·06
Alumina,	11·38
Potassa,	10·44
Water,	43·12
Loss,	1·00
	100·00

IMPURITIES.—The purest kinds of alum always contain a little iron; that from Liege contains 0·02 per cent.; that from Gavelle, near Paris, 0·08 per cent.; that from Aveiron, 0·11 per cent.; and English alum contains 0·12 per cent. This admixture of iron alum, which is easily detected by ferrocyanide of potassium, is sufficient to impair the delicate colors imprinted upon cloth; it can, however, be removed by recrystallization, or, as prussian blue, by means of yellow prussiate of potassa. Only the Roman alums—a name given to all varieties of alum imported from Italy—are sufficiently pure for immediate use, and are highly prized on account of the minuteness of the quantity of iron which they contain, although their outward appearance would naturally lead to the contrary assumption.

These varieties consist of small disconnected crystals, covered externally with a kind of reddish mud, which is stated by some to be void of iron; on the alum being dissolved, however, in water, none of this coating is acted upon, and the quantity of iron alum present in the solution, does not exceed 0·005 per cent. Alum of this description produces a blue precipitate, with the aforementioned reagent, only after standing several hours, while ordinary alum affords a precipitate in a few minutes. Roman alum is generally crystallized in the form of octahedrons, but cubical crystals are occasionally found, hence the name *cubic alum.* The composition of Roman alum, and the circumstances which occur during its formation, have not been minutely investigated; its reactions differ from ordinary alum in many respects. When the cubical crystals of Roman alum are dissolved in water, at a temperature ranging between 96° and 104° Fahr., and the solution is set aside to crystallize, the alum is again produced in cubes, which appear more certainly if the liquor be left to spontaneous evaporation. At a higher temperature, the solution becomes turbid from the separation of basic alum, and the clear liquor deposits the substance in octahedral crystals: hence it may be inferred, that the Roman cubic alum is formed in the presence of an excess of alumina in the crystallizing alum liquor. When octahedral alum is digested with hydrated alumina, and the solution allowed to evaporate spontaneously by exposure, cubical crystals are formed with a simultaneous separation of a basic salt of alumina; the crystals have an acid reaction, and the same properties as ordinary octahedral alum.

In a paper recently communicated to the Parisian Academy of Sciences, by M. **LOEWEL**, upon the identity of octahedral and cubical alum, and the production of the latter, the author remarks, that on account of cubic alum being regarded as a basic salt, and as containing more alumina than the ordinary octahedral alum, he was induced to institute the experiments of which the following is an epitome:—

The idea of cubic alum containing more alumina, arose from the fact that in making alum in the ordinary way, by dissolving the materials in water, its solutions never deposit cubic crystals, neither by cooling nor by spontaneous evaporation, unless hydrate of alumina has been previously dissolved in them, or a certain quantity of an alkaline base has been added to withdraw from the sulphate of alumina a part of its acid. All the chemical treatises state, notwithstanding the preceding opinions among chemists and manufacturers, and very apropos, that dimorphous crystals have the same composition; definite proof has not, apparently, hitherto substantiated the proposition, and without this, such statements are in open contradiction to the observed phenomena that cubic alum, when dissolved in water, and recrystallized under the octahedral form, deposited a certain quantity of basic sulphate of alumina.

Having submitted the salts in question to a chemical examination, **LOEWEL** obtained results which seem to dissipate all doubts upon this point. He prepared, in the usual manner, *pure* potassa and ammonia alums, and crystallized under the ordinary octahedral system. During this part of his labors, he states that, in many of the alums of commerce, the sulphate of potassa in the alum is partly replaced by sulphate of ammonia, but the proportionate quantity of the latter is very variable.

To obtain the cubic crystals of alum, the pure substance stated above was dissolved in three or four times its weight of water, heated from 72° to 81° Fahr., and an aqueous solution of potassa in alcohol added in successive small portions, till the subsalt of alumina, thrown down by each addition, was no longer dissolved upon the agitation of the liquid.

Cubical ammonia alum was procured by dissolving the pure octahedral salt which had been prepared in three to four times its weight of water at 113° Fahr., and adding ammonia with the same precautions as the potassa in the preceding instance, till the small quantity of subsalt ceased to dissolve in the solution. The spontaneous evaporation of the potassa and ammonia alum solutions, at the ordinary temperature, afforded the crystals in cubes. The author, however, observed, that in some of the operations performed, the first crystals deposited were still octahedrons, while, in others, they assumed, after the lapse of some days, the form of beautiful transparent perfect cubes; and lastly, other solutions became ambiguous, and showed a cloudy appearance before depositing the crystals.

The form assumed by the salt after adding a quantity of potassa—representing about one equivalent and a half, that is, on taking from the sulphate of alumina contained in the alum nearly the half of its acid—was that of truncated and cubical octahedrons; but on a further addition of a little alkali, cubes were formed.

When the potassa solution was added by very small portions at a time, and with much precaution, it was found that a quantity representing nearly one equivalent and three-quarters, might be introduced before obtaining a precipitate which no longer completely dissolved by long agitation of the liquid; such solutions, however, though quite clear after being filtered, became cloudy after some time before depositing crystals.

It appears from the preceding, that it is necessary to abstract at least one-half of the acid contained in the sulphate of alumina in the alum, before the crystals are obtained in cubes. When some of the solutions thus prepared had given a certain quantity of cubic crystals, but not nearly the amount of that contained in the liquid, the solution then became cloudy by degrees, and deposited a gelatinous tribasic sulphate of alumina. The alum subjected to the experiments afterwards to be described, was taken from the mother liquors before they became cloudy, in small beautiful transparent crystals, of from half to one inch in the length of the sides: the crystals were washed and dried before each experiment.

On dissolving the two salts in water, perfectly clear menstrua were obtained, which remained so even during their concentration, and furnished, on cooling, truncated octahedrons. The cold solutions of the salt, even without concentration, afforded a like result. The octahedral alum salt procured in this way had exactly the same weight of alum as was dissolved of the cubic alum, without a vestige of basic salt separating during the operations. Many who experimented on cubic alum, and stated that a portion of basic salt was thrown down, must have employed large opaque crystals obtained in the clouded solutions, and in this case the basic salt was simply interposed, and formed no integral part of the crystals.

The potassa and ammonia cubic alum described were found to resist the action of air dried by sulphuric acid in a bell-jar for weeks without efflorescing, although, in all chemical treatises, it is said that alum effloresces very slowly in the air. LOEWEL suggests that it would be more correct to state that no efflorescence takes place. He placed crystals of pure alum under bell-jars, in which the air was dried by sulphuric acid; at first the crystals lost some thousandths of their weight of interposed water, but afterwards remained for several months, even for a whole year, at a temperature rising to 77° Fahr., without parting with the smallest quantity of water.

The small cubic crystals were exposed several hours to a temperature from 158° to 185° Fahr., and then to 212° Fahr.; after a while the heat was raised more and more, to about 680° Fahr.; the total loss in water amounted to 45·5 per cent. Corresponding results were obtained by treating, in a similar manner, small octahedrons of the pure salt; hence, the alum under both forms contains exactly the same per centage of water of crystallization. The method of expelling the water pursued, as in the foregoing, was found to answer exceedingly well, inasmuch as, by such an application of the heat, the aqueous fusion, and consequent intumescence, were avoided.

During the drying it was observed that the crystals effloresced, and became a little agglutinated, losing at the same time, in a slight degree, their crystalline form, but without intumescence.

The sulphuric acid which the alum contained was determined by precipitating its boiling solution with an excess of chloride of barium in the usual way.

The annexed analyses show the correspondence of the sulphuric acid obtained in three experiments, with the calculated amount:—

Composition.	Atomic weight.	Theory.	Found.		
			I.	II.	III.
4 Eqs. of sulphuric acid,...	160 ..	33·72 ..	33·92	33·62	33·88
1 Eq. of alumina, ...	52 ..	10·83 ..	—	—	—
1 Eq. of potassa,.........	47 ..	9·93 ..	—	—	—
24 Eqs. of water,..........	216 ..	45·52 ..	45·5	—	—
	475	100·00			

Hence, it is evident that the salt contains the same number of equivalents of sulphuric acid as ordinary alum crystallized in octahedrons.

The determination of the acid in the ammonia salt was conducted as in the analysis of the potassa; the alumina was ascertained by the total decomposition of the salt by heat, in the following manner:—After the alum had lost about 47 per cent. of its weight, the small capsule of platinum wherein the salt was weighed, was enclosed in a platinum crucible, and this again enveloped in a hessian one, which was surrounded with incandescent coals in a furnace, mounted with a chimney of plate-iron.

When at a very intense heat, the salt no longer lost in weight; on reweighing the crucible, the content of alumina was obtained.

The subjoined are the analyses of the ammonia alum, which agree closely with theory :—

Composition.	At. weight.		Theory.		Centesimally represented. Found. I.	II.	III.
4 Eqs. of sulphuric acid,	160	..	35·29	..	35·34	35·18	35·27
1 Eq. of alumina,......	52	..	11·34	..	11·57	11·45	11·5
1 Eq. of ammonia,.....	26	..	5·73	..	—	—	—
24 Eqs. of water,........	216	..	47·64	..	—	—	—
	454		100·00				

Octahedral crystals of the same salt were submitted to decomposition by heat, and the analysis agreed in every point with the preceding.

LOEWEL defines the circumstance which gives rise to the deposition of cubic alums, as being the effect of an action of contact exercised over its molecules by the solution of aluminated alum, in the midst of which it is formed and slowly deposited.

NEUTRAL ALUM.—This kind is much preferred in many arts where alum is employed, and especially among the printers of fabrics, on account of the greater amount of basic salt which it deposits than the ordinary substance, from which it differs only in not containing free acid.

To prepare it, alumina is often added to ordinary alum; a better method is to abstract the free acid by adding an alkali, such as carbonate of soda, or carbonate of potassa, to a solution of ordinary alum, as long as the precipitate which appears at first is redissolved. This affords the *neutral alum*, which is essentially a solution of ordinary alum, with a certain proportion of basic sulphate of alumina.

COMMERCIAL SULPHATE OF ALUMINA.—It has been stated that the presence of an alkaline sulphate is not essential in those processes in which alum is employed; it is, indeed, rather objectionable than otherwise. A substance has recently been introduced into commerce under the name of alum, which is very much more efficacious than the crystalline salt; it occurs in four-sided plates about an inch in thickness, which are white and partially translucent, dissolve perfectly in water, exhibit no trace of crystallization, and possess the peculiar taste of alum in a more marked degree than even alum itself. This substance is entirely free from iron. The process for its preparation, and for which WIESMANN has taken a patent, consists in treating clay with sulphuric acid in the manner before described; and differs only in adding no sulphate of potassa to the solution of sulphate of alumina, but precipitating any iron that may be present by adding ferrocyanide of potassium, evaporating to the consistence at which the mass will solidify when cold, and then pouring it into the *melting vessel*. MOHR found this substance, which is improperly called alum, to be perfectly free from iron, and to contain

Alumina,..........................	13·91
Sulphuric acid,.....................	36.24
Water,..............................	49·60
Sulphate of potassa,................	1·50

The latter ingredient is due to the small portion of potassa naturally existing in all clays. The preceding composition corresponds exactly with the combinations of

7·1 per cent. of ordinary potassa alum, and
92·9 " of sesquisulphate of alumina.
The formula of which is $Al_2 O_3 3 S O_3 + 18$ aq.

A sample of this preparation from the Morley Works, near Plympton, which was analysed by the Editor, gave the annexed quantities of the respective ingredients:—

	Centesimally represented.
Alumina,............................	17·820
Sulphuric acid,......................	33·178
Water,..............................	49·002
Lime,................................	a mere trace.
	100·000

These numbers correspond with the formula,

$$2 Al_2 O_3, 5 S O_3 + 33 \text{ aq};$$

thus showing it to be a basic sulphate.

The objection which manufacturers urge against this compound is, that from its physical appearance it is impossible to judge of its purity in the same way as common alum.

WIESMANN'S process for the preparation of pure sesquisulphate of alumina has been found the most effectual and economical; it consists in agitating the solution of sulphate of alumina in a large wooden vessel with ferrocyanide of potassium.

The vessel wherein the mixture is made is similar to A, in Fig. 101. After allowing the bulk of the precipitated prussian blue to subside, the supernatant liquor is run off into the wooden vessels, B B B, where it remains until perfectly clear and free from precipitate, after which the clear liquor is treated as has been already described.

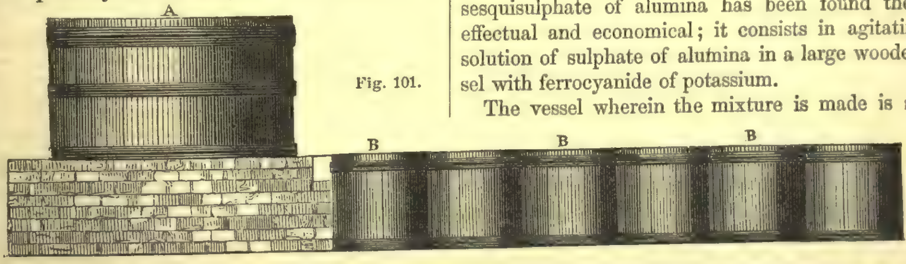


Fig. 101.

The precipitated prussian blue is repeatedly washed with cold water to separate the whole of the sulphate of alumina, and the solutions are drawn off into some of the vessels, B, for the above object.

The prussian blue is now treated with a lie of caustic soda to separate the iron, and thus the same precipitant serves for a longer period with very little loss.

RICHARDSON'S analysis of this sulphate, after the iron had been separated by the above process, is—

Sulphuric acid,.........................	35·95
Alumina,................................	14·25
Lime,...................................	traces
Magnesia,...............................	traces
Chlorine,...............................	traces
Water,..................................	48·05
Loss,...................................	1·75
	100·0

When the crude sulphate of alumina is lixiviated, there remains a refuse matter that contains some sulphuric acid in the form probably of subsulphate, and which resists the solvent action of water.

Two samples of this residuary matter gave the annexed results:—

Silica,	41·85	39·05
Alumina, with traces of sesquioxide of iron,	18·40	25·55
Sulphuric acid,	4·45	8·47
Sulphate of lime,	4·01	traces
Water,	29·53	27·50
Loss,	1·76	—
	100·00	100·57

The Editor has been informed by several of the first manufacturers—those at Whitby in Yorkshire, and Hurlet, near Glasgow—that during the few last years the alum trade has been so depressed that the produce scarcely balanced the expenditure, owing partly to an unwise competition; and that many makers would have ceased operations, but having the works on hand, free of other expenses, exclusive of the labor, it was thought advisable to continue them. In the market, alum commanded only eight pounds per ton during the last year, but at present the price is from ten pounds to ten guineas, and at this rate promises a remuneration.

A proper and reliable estimate of the quantity of alum fabricated cannot well be made, since it is an article which affords no convenient means for ascertaining it—being free of duty—except by consulting the note-books of all the manufacturers, an inspection which would, on private grounds, and perhaps with reason, be refused. On an average, the quantity manufactured may be computed to be at least about ten thousand tons annually, of which there is reason to believe from four to five thousand tons are manufactured in Scotland.

USES.—This salt is largely employed in the arts, chiefly in consequence of the affinity which alumina, its primary base, has for coloring and other vegetal matters; for gelatine, and a number of like bodies. The fibre of cotton, wool, *et cetera*, has such an affinity for alumina, or a basic salt of the base, that when immersed in a solution of alum, a basic salt adheres to it so firmly that it cannot be removed by washing.

This basing with aluminous salts, enables the cloth to unite with larger quantities of the coloring matter, and retain it with greater persistency. Some precautions are to be observed in its use in the hands of the cloth printer, which will not here be entered into, as they will form a part of the subject to be treated of, in a future part of this work, under CALICO-PRINTING.

Alum is used in preparing white leather, called *tawing;* to clarify water, by the combinations which it forms with the foreign matters present, and also in the preparation of bookbinder's paste. A large quantity of alum is taken medicinally, as a topical and internal remedy in various diseases. Alum mixed with gypsum —sulphate of lime—forms the chief ingredient with which the outer chambers of MILNER's fire-resisting safes are lined, so as to protect the interior depositories from being injured. This it does from two causes: firstly, the large quantity of water it contains, which helps to moisten the inner chamber when the box is heated, and so prevents the contents from being consumed; and secondly, from the non-conducting power of the mixture after the water is expelled.

A better salt could not have been patented for this purpose, and the great success which has attended the application is the best testimony to its efficiency.

Alum is the compound employed for preparing most of the salts of alumina, particularly red liquor, already described at page 36.

ALUMINA.—This is the base of the alums, which contain sesquisulphate of alumina as one of their constituents, and the utility of alum in calico-printing rests solely upon this earth. Alumina is likewise extensively used, united with silica, in the manufacture of all kinds of earthen and porcelain ware; in the manufacture of crucibles, mortars, and cements. It is particularly employed, almost in its purity, for the manufacture of *glass pots*, where the refractory power of the earth is such as to permit the fusion of the *frit* while they remain unaltered, either by the intense heat, or by the molten substances.

Alumina occurs on the surface of the earth in a pure state only in some rare minerals—for example, the corundum, the sapphire, and the ruby; but it constitutes a large proportion of all the slaty and shaly rocks. It is the main ingredient also of pipe-clay and argillaceous soils, which increase in tenacity in proportion to the quantity of alumina they contain.

Though it exists so largely in the soil, it contributes but little in a direct manner to the *nourishment* of plants, as the ash they leave contains, in general, *a very small quantity* of alumina.

Preparation.—Alumina may be precipitated from any of its solutions by an alkali, as a bulky, white, amorphous powder, which, when collected, well washed, and dried, is pure. It is a white, tasteless, earthy substance, adheres to the tongue, has a specific gravity of 2·00, and is insoluble in water, but dissolves easily in caustic potassa and soda, and in most acids, at least when newly thrown down. When heated to redness, however, it becomes hard and dense, as in burned clay and firebricks, and can then only be dissolved with extreme difficulty, even by the strongest acids.

In combination with phosphoric acid, alumina forms one compound well known to mineralogists, by the name of *wavelite*, which occurs, however, in too small a quantity to be an object of interest to the manufacturer.

One of the most difficult problems in analytical chemistry, is to effect a perfect separation of a small proportion of phosphoric acid from alumina, and rigorously to estimate its quantity; hence, in the greater part of the analyses of soils hitherto published, this most important ingredient in a fertile soil—phosphoric acid—when in combination with alumina, has either been altogether neglected, rudely guessed at, or indicated only by a rough approximation. There is no direct proof, therefore, of the extent to which the phosphates of alumina exist in different soils.

Alum has not been extensively tried as a manure. Its composition, however, would lead one to expect it to exert a beneficial influence on the growth of many roots, especially turnips. SPRENGEL has experimented with it, and considers it worthy the attention of agriculturists.

AMMONIA.—*Ammoniaque*, French; *Ammoniak*, German.—In the gaseous state, ammonia is synonymous with the *alkaline air* of PRIESTLEY, *volatile alkali, et cetera;* in the liquid state, with the caustic spirit of sal-ammoniac.

Gaseous ammonia was probably known to the ancients, though no record of the fact remains to prove it; still, as the manufacture of ammoniacal salts was a source of trade among the Egyptians, it is very probable the pungency of the gas was familiar to them. The scientific development of this compound remained for Dr. BLACK, who, in 1756, first isolated it, and proved its distinction from the sesquicarbonate of this base; PRIESTLEY afterwards, with greater accuracy, in a more lengthened investigation, prepared it in a pure state, and discovered more of its properties.

Ammonia, though not very extensively disseminated in nature, is to be met with in a great many vegetal products; the decomposition of animal matter, either by putrefactive fermentation or destructive distillation, yields it in moderate abundance; it is also found united with acids in many strata of the mineral kingdom. In the atmosphere, very minute portions of ammonia are present, which exert a most beneficial influence upon vegetation. Volcanic districts are highly productive of ammonia, standing second in this respect only to the guano islands of South Africa. Sea water contains a low decimal per centage of ammoniacal salts; fresh water also holds it in combination, but in an infinitesimal proportion. A perceptible quantity of this alkali, generally combined with acids, is found in mineral springs; soils almost universally contain it—more especially, however, those of the ferruginous and argillaceous class. In many substances where ammonia is apparently absent, a careful and patient investigation may prove its presence; and often where it is detected unexpectedly, it is precipitately judged that its formation may be owing to the unusual direct combination of hydrogen with the nitrogen of the atmosphere, whereas a calm and considerate review of the materials, and of the circumstances attending such operations, may lead to a more simple and conclusive demonstration of its presence. Thus, it occurs in the atmosphere; apparently no ammonia exists in it when performing an analysis, but on examining rain water recently collected in town or country, an expert chemist will detect it in minute quantity.

Animal recrements, especially those of reptiles, are rich in ammoniacal compounds.

Preparation.—It may be prepared in the laboratory by a very simple process, and one which is familiar to every student in chemistry; namely, by heating an ammoniacal salt with hydrate of lime in a retort, and collecting the eliminated alkaline vapor over mercury, or by displacement of air. This operation, though simple, requires—like all those conducted on the small scale—care and skill, to obtain a pure product. The decomposition which takes place in the preceding instance, supposing that chloride of ammonium had been employed, is the following:—

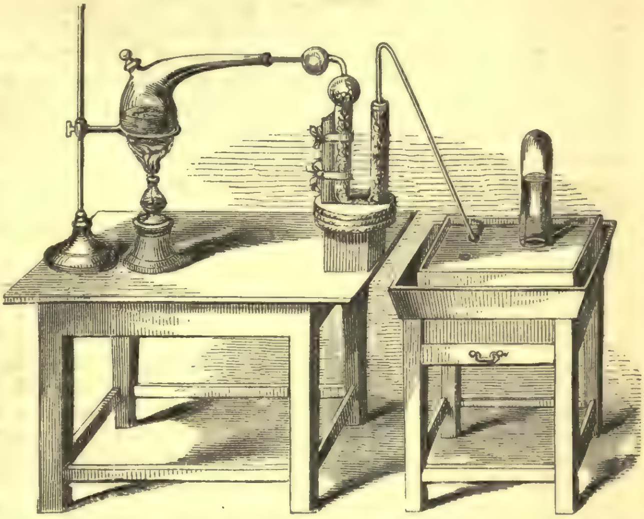
$$\underbrace{NH_4Cl}_{\text{Chloride of ammonium.}} + \underbrace{CaOHO}_{\text{Hydrate of lime.}} = \underbrace{NH_4O}_{\text{Ammonia.}} + \underbrace{CaCl + HO.}_{\text{Chloride of calcium and water.}}$$

By desiccating the NH_4O over lime, previous to its reaching the mercurial trough, an atom of water is withdrawn, and the gas which enters the jar has the constitution represented in the annexed equation—

$$\underbrace{CaO}_{\text{Lime.}} + \underbrace{NH_4O}_{\text{Ammonia.}} = \underbrace{NH_3}_{\text{Ammoniacal gas.}} + \underbrace{HO, CaO}_{\text{Hydrate of lime.}}$$

The arrangement in Fig. 102 is well adapted for the preparation of ammoniacal gas: equal weights of the chloride of ammonium and hydrate of lime are intimately mixed, and introduced into the retort; heat is applied, gently at first, and then gradually increased till vapor ceases to be evolved—chloride of calcium remains.

Fig. 102.



In a chemical point of view, ammonia is generated in various and curious ways; as, when an excess of hydrogen is burned in the atmosphere, nitrate of ammonia is formed; when iron oxidizes, from the decomposition of water, sesquioxide of iron and ammonia result. A similar combination is formed when hydrate of potassa, soda, baryta, or lime, is heated in the air, or in hydrogen, with iron, zinc, lead, tin, or arsenic. REISET explains its formation in hydrogen as arising from nitric oxide—deutoxide of nitrogen—derived from the sulphuric acid used to prepare the hydrogen, and adduces as a corroboration the fact, that when iron filings are heated in a strong solution of potassa to 266° Fahr., they evolve hydrogen and ammonia, both when heated in air, and in hydrogen containing nitric acid, but not in pure hydrogen. When nitrous oxide and an excess of hydrogen are transmitted over platinum black—spongy platinum—in the cold, no ammonia is formed; but if heat be applied, it is produced in considerable quantity. A dilute solution of nitro-sulphuric acid—composed of a hundred volumes of water, four and a half of sulphuric acid, and four of nitric acid—dissolves iron, zinc, or tin, without giving off nitric oxide, or hydrogen, although these bodies always result from the decomposition of nitric acid and the solution of the forementioned metals. In this instance, the hydrogen evolved from the solution of the metal combines with the nitrogen of the nitric oxide, and gives rise to the alkali.

Ammonia is a volatile, irrespirable gas, though, when diluted with air, it may be inhaled. Its odor is extremely pungent; it possesses a strong alkaline taste; turns reddened litmus paper blue, and turmeric paper brown; is very slightly inflammable, and extinguishes those bodies which are in a state of combustion. It is composed of two volumes of nitrogen and six of hydrogen, condensed into four volumes of the gas. The specific gravity of the vapor is ·5890, air being taken as unity.

By a pressure of six and a half atmospheres, at the ordinary temperature, it is condensed into a transparent colorless liquid, of 0·731 specific gravity at 60°; a like result is obtained at the ordinary pressure of the atmosphere, by reducing the temperature 40° below zero. It is a very subtle, colorless liquid, which, according to FARADAY, freezes into a white translucent crystalline substance at —103° Fahr. On heating one volume of the liquid to 60°, at a barometric pressure of 30·2 inches, it formed 1009·8 volumes of the vapor.

BERTHOLLET states that ammoniacal gas is composed of—

	Atomic weight.	Theory.	Berthollet.
1 Eq. of nitrogen,......	14	82·35	81·13
3 Eq. of hydrogen,......	3	17·65	18·87
1 Eq. of ammonia,......	17	100·00	100·00

Ammonia is decomposed with facility by heat in the presence of a body which contains oxygen that is not difficultly transferable; hence, if the higher oxidized compounds of nitrogen be brought into contact with ammonia, and both compounds are mutually decomposed, water and a lower oxide, with the occasional elimination of nitrogen, are the result. When transmitted over many metallic oxides at a dull red heat, it is decomposed into nitrogen and hydrogen; the latter abstracting oxygen from the oxide and forming water. The most interesting change, however, is that which produces cyanogen, and this, uniting with undecomposed vapor, produces cyanide of ammonium, while hydrogen is set free; it is effected by transmitting the ammoniacal gas over heated charcoal. The accompanying formula serves to explain the action :—

$$\underbrace{2\,N\,H_3}_{\text{Ammoniacal gas.}} + \underbrace{C_2}_{\text{Carbon.}} = \underbrace{N\,H_4\,C_2\,N}_{\text{Cyanide of ammonium.}} + \underbrace{H_2}_{\text{Hydrogen.}}$$

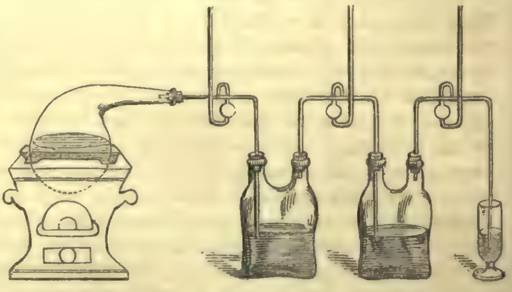
In point of utility, the gas possesses but little interest.

LIQUID AMMONIA.—*Salmiakgeist*, German; *esprit de sal ammoniac*, French; synonymous with *caustic ammonia*, and *spirit of hartshorn*.—The preparation of liquid ammonia is one among the many manufactures which have sprung up in consequence of the rapid progress of science and art during the last half century; but it seems to have risen to its present state simultaneously with that of gas-lighting. Considerable quantities of crude liquor ammonia are produced as one of the by-products of the distillation of coal; hence, within the last twenty-five years, the establishment of factories for the preparation of ammonia and its salts has gradually taken place, from the metropolis to almost every provincial village where gas is consumed. The demand for animal charcoal opened another extensive supply of ammonia, for it is evolved during the destructive distillation of the bones from which the animal charcoal is prepared for the sugar refiner and others; and as soon as the spirit of enterprise and emolument induced the capitalist to turn his attention to the manufacture, various other sources were discovered which yielded this alkali. The principle on which ammonia is generated on the large scale, differs in nothing from the processes already stated; and the formation of the solution of the alkali rests upon the property which water possesses of absorbing it. Water, at a temperature of 50° Fahr., condenses about six hundred and seventy times its bulk of ammoniacal gas—seven hundred and eighty according to THOMSON; by this retention the bulk of the solution is increased considerably—so much so, that six volumes of water, on becoming saturated with the gas, increase to ten volumes, and the specific gravity of the liquid is reduced from 1·00 to 0·785.

Liquor ammonia is prepared in the laboratory by taking a mixture, such as that before prescribed, and introducing it into a glass or earthenware retort, the neck of which is connected with a series of Woulfe's bottles, nearly filled with water, as described at page 73. It is necessary that the lime used should be slaked in about four parts of water, previous to its being mixed with the powdered ammoniacal salt, as by that means the ammonia will be more freely disengaged, and with less heat than when only a small quantity of moisture is present.

Fig. 103 is a representation of an apparatus which answers the purpose remarkably well.

Fig. 103.



During the decomposition, the heat should not be too briskly applied, and in no case should the bottom of the retort be raised to redness, as portions of the salt would be sublimed without being decomposed; and, by passing over to the first bottle, would render its contents unfit for use. To guard as much as possible against the sublimation of the salt, the tube connecting the retort and first bottle should have a considerable calibre; and it is often advantageous to append a large bulb or balloon between the mouth of the retort and first condenser, in order that any portion of the sublimed salt which might be driven off towards the end of the operation, may be arrested before it is carried into the ammoniacal liquor. The greatest precaution is to be taken in having all the connections air-tight, to prevent the escape of vapor. When the whole of the ammonia is driven off, it is necessary to raise the temperature a little higher than usual to fuse the chloride of calcium; and as soon as this takes place, the retort should be disjoined from the condensing bottles, and the fused salt poured out as speedily as possible. Very often the retort breaks at this part of the operation, in consequence of a layer of the salt solidifying upon its neck, which, on being exposed to the air readily absorbs moisture, and partly dissolves; the solution thus formed cools considerably, and on penetrating through the undissolved portion of chloride of calcium to the retort, which still retains a high degree of heat, the particles with which it comes in contact are suddenly contracted, and the retort cracks. Should the retort escape fracture at this part of the process, it generally happens that it is broken when heat is applied for a second operation; hence it is rare to find a retort, even when carefully handled, that will stand two operations. Lest any of the undecomposed salt may be eliminated, it is best to use only a small quantity of liquid in the first receiver, and return the product into the retort upon a second operation; the contents of the second and third bottles should be retained as pure.

Uses of Ammonia.—Ammonia is in daily requisition as a reagent for the analytical chemist. It offers peculiar facilities in the preparation of many compounds on account of its great volatility, as also that of its salts, and as being an almost universal precipitant of the oxides of the heavy metals. In medicine, ammonia is used to a moderate extent to alleviate spasms, for rousing the vascular and respiratory system, as an antacid, and in various other cases. It is extensively employed in bleaching and calico-printing, in color manufactories, and other important trades.

When ammonia is manufactured on the large scale from ammoniacal salts, the sulphate of the alkali is for the most part preferred; but there is no material deviation from the directions already laid down, except that another kind of apparatus is used, to avoid the loss of retorts which is incurred when preparing it in the laboratory. It is particularly necessary, when working upon the large scale with condensers in the form of Woulfe's bottles, to have the joints well luted; this is effected by covering each connection with a paste made of white of egg and chalk intimately ground. A better composition is produced by blending wax, resin, and turpentine together; this should be applied upon the connection of the tubes and tubulures of the condensers in moderate thickness. If this point is not attended to with care, the pressure upon the gas forces it through into the atmosphere, causing the workmen considerable annoyance till arrested.

Fig. 104 is a vertical section of an apparatus which answers well for the preparation of ammonia on a large scale.

A is an iron retort, placed in sand, over the fire *g*, of which *h* is the ash-pit, and *x* the chimney; *a* is the stopper, and *b* an iron pipe connected to the neck of the retort, and reaching some distance from the furnace to the end of the tube, *c*, which may be either of glass or lead. B is the first condensing vessel, and is supplied with three tubulures, through the middle one of which a safety tube is inserted. *e* is a stopcock and pipe, by which the contents of B are drawn off when requisite. This vessel is left nearly empty, for the purpose of purifying the gas of any traces of ammoniacal salt which may be carried over, and also for retaining traces of oily matters which are invariably present, either from the impurity of the salt employed, or from the grease with which the stopper is besmeared to prevent it from adhering too tightly in its place. B is connected with other condensers, of which only one, C, is seen in the figure; these vessels are filled to about three-fourths of their capacity with water, and so rapid is the absorption of the gas, that scarcely a trace of ammonia escapes from C, till the solution contained in it is completely saturated.

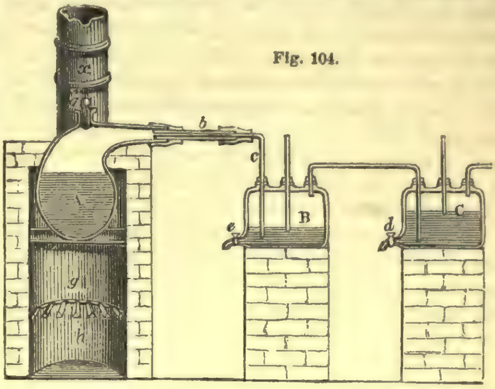


Fig. 104.

When this happens, the solution of ammonia is drawn off by the stopcock, *d*, and the very weak liquor in the third condenser supplied instead, or it is recharged with a fresh quantity of water.

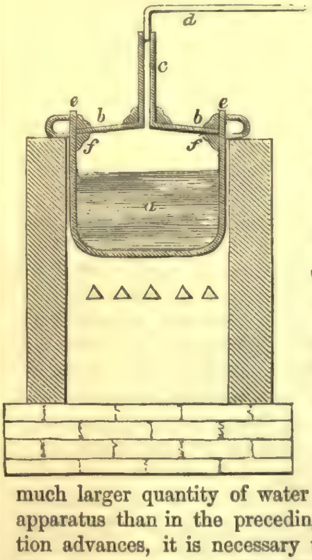
In this process it is very easy to produce, at each operation, an ammoniacal liquor of any standard strength, by furnishing each condenser with a glass gage pipe, graduated into equal parts, showing the bulk of liquid in the interior. Whatever be the quantity of water introduced, it expands in the ratio of six to ten, as before stated, on being completely saturated with the alkaline vapor, or in less proportion according as its gravity is reduced. At the first working, the measure of water employed is noted, and also the proportion of expansion, till it approaches that point which, by calculation, is found to correspond with the strength of the liquid required; this may be corroborated by drawing off portions repeatedly, and taking their density, and from this number the quantity of ammonia is ascertained by the aid of tables, which will be found further on. As soon as the exact point is gained, the gage is scratched at the level of the liquid, and this one test will serve for all future operations where the ammonia is to be made of the same strength; but it is necessary that the bulk of liquid should be always equal to that used in the first experiment.

When gas ceases to be evolved from the mixture in the retort, the fire is partly urged, and the stopper removed by means of a lever. If the stopper be so firmly fixed that it cannot be readily displaced, a cloth moistened with cold water should be carefully wrapped round it, without touching the neck of the retort; this refrigeration causes a contraction in its particles, and will enable the operator to remove it with facility. The residue—which is fused chloride of calcium, in the event of the chloride of ammonium being used—is then ladled out. Should sulphate of ammonia be operated upon, considerable quantities of water are employed, and the distillation should never be allowed to proceed to dryness, as in such a case the sulphate of lime formed would constitute a concrete on the bottom of the retort, which could not be removed without much labor and loss of time.

All the ammoniacal impurities which have collected in B during the first distillation are drawn off, and introduced into the retort in the second operation, to obtain the ammonia which they hold, and a small quantity of fresh water is substituted, to cover the lower end of the safety tube, as in the preceding operation. This apparatus, when once erected, will last for a long time.

A modification of the foregoing apparatus, represented in the annexed cut—Fig. 105—is sometimes employed.

Fig. 105.



a is an iron kettle, to which a metallic lid, *b b*, is adapted, resting upon blocks or ledges, *f f*, in the interior of the vessel. The lid is rendered air-tight by means of other bars of metal, *e e*, which are soldered fast on the outside over the interior ones. From the middle of the cover an iron pipe, *c*, rises, to the orifice of which another pipe, *d*, bent at right angles, is soldered, for the purpose of conducting the ammoniacal vapor to the condensers, which are similar to those already described. A much larger quantity of water must be used in this apparatus than in the preceding one; and as distillation advances, it is necessary to keep up the supply throughout the process, that the solder may not melt, a circumstance which would happen were this precaution overlooked.

Latterly, as the demand for ammonia and its salts became greater, its manufacture received an additional impetus, and several patents have been granted for its preparation; most of them, however, relate to the production of the salts of ammonia. Those patents which are considered to be improvements on the processes for obtaining ammonia directly for the manufacturer, as well as for other requisites, will be here noticed.

Mr. YOUNG, in 1841, took out a patent for preparing ammonia from guano; the method which he recommends is the annexed:—The retorts are filled vertically with two parts by weight of guano, and one part by weight of hydrate of lime, or other caustic alkali, and the whole is intimately mixed by the aid of an agitater placed in the retort. Having well mingled the materials, the retorts are moderately heated, and this heat is gradually increased to redness. The combined action of the heat and alkaline compounds disengages all the ammonia, whether it be in the form of salts or other complex bodies, such as urea or uric acid, and the gas thus liberated is received into a condenser filled with water. Other gases and fluids are evolved together with the ammoniacal vapor, the uncondensable portions of which pass through the condenser unaffected.

An ammoniacal solution is obtained by the destructive distillation of bituminous schist, for which a patent was granted in 1841 to COUNT DE HOMPESCH, who rendered it available for the manufacture of ammoniacal salts.

The method adopted under WATSON'S patent for procuring ammoniacal liquor from gas water—sealed in 1838—is as follows:—The gas water is run into a capacious retort, and a suitable quantity of slaked lime added—the amount being determined by the quality of the crude liquor; heat is then applied, and ammonia, tolerably pure, distils over, which, on being received in a vessel of cold water, forms an ammoniacal liquor. When considerable quantities of steam are observed to pass over with the vapor of ammonia, the strong alkaline solution already formed is removed, and this the patentee calls *the first portion;* that which is collected afterwards, by continuing the distillation, he names *the second portion;* the latter is weak or impure, and is returned to the boiler, with a second charge of lime and crude liquor, to undergo another distillation. The first portion from the previous operation is introduced into the retort, mixed with a small quantity of lime, if necessary, and as soon as the disengaged vapor carries steam with it, the strong liquor in the condenser is to be drawn off as before, and this he calls *the first portion of the second distillation.* The distillation is continued as long as it yields ammonia, and this secondary product is returned to the retort as before. The first portion of the second distillation is a concentrated liquid of sufficient purity for all ordinary purposes of scouring, cleaning, *et cetera*, but it may be still further improved by distilling a third time, in the same way as already directed, observing that the portion of solution which is made by the absorption of the ammoniacal gas is preserved, and the residue transferred again to the retort.

By far the most valuable of those methods which have been of late years submitted to the public, is that for which Mr. NEWTON took out a patent in 1841; it consists in the application of COFFEY'S still, described at page 76, but with a few modifications to adapt it to the distillation of the gas water. By its use the ammonia may be produced of any density up to its most concentrated state, and, consequently, of corresponding purity. Having made the reader already acquainted with the still in its application to the whisky trade, it will be unnecessary here to enter into lengthened details; those specific alterations which are peculiarly required by the operation, will, however, be pointed out. The number of diaphragms in the apparatus is increased or diminished according to the strength of the product which is to be produced, and the whole apparatus may be constructed of wood lined with sheet-lead, having the diaphragm plates in the interior of the analyzing column formed of perforated sheet-iron. Each of the sheets is supplied with several small valves, so weighted as to open upwards whenever the elastic vapor below the plate exerts more than a certain amount of pressure upon them. The ammoniacal crude liquid which enters at the top, passes downwards through each diaphragm successively, by means of a pipe rising about one inch above the level of the plate, the lower end of which is encased in a cup fixed upon the next diaphragm. The pipe must be sufficiently capacious to carry off all the liquid which enters at the top, and as the solution descends, it fills the small cup, and prevents the vapor from ascending at this part of the plate. Steam, as usual, is the medium which effects the elimination of the volatile body. According as the ammonia is to be procured, the supply of liquor, and the entrance of steam beneath, are regulated. When it is necessary that the ammonia should depart from the top of the rectifying column in the form of gas, the flow of liquid should be in proportion to the ascending steam, in order that the liquor in the top diaphragms may remain at little more than the normal temperature of the atmosphere, but become hotter as it falls towards the under reservoir, where it is retained for some hours at a boiling heat, to expel all the alkali. On the contrary, when it is necessary that the ammoniacal vapor should be in company with much steam, the stream of liquid entering is elevated to nearly its boiling point in the top diaphragms, by means of the larger volume of steam which is admitted from the boiler. Concentrated or dilute solutions of ammonia may in this way be obtained at once from salts, the acids of which are removed in the usual manner with lime or alkali; a product of considerable purity is also derived from the ammoniacal liquids formed by the distillation of bones or other animal matters; but, before submitting such liquids to the action of the heat, it is necessary to remove most of the impurities, and the combined acid, by the action of lime.

It is customary to have the diaphragms bent upwards, alternately, at opposite sides, so as to conduct the liquid from right to left, and conversely, till it reaches the bottom.

Carbonic acid gas, and other volatile compounds, which do not impair the use of ammonia in certain applications, may be eliminated from this still with the ammonia; but, in this case, as much steam should be generated in the liquor as will effectually prevent the solidification of the ammonia by the carbonic acid.

The specification of LAMING's patent recommends that the solution of carbonate of ammonia, as obtained from bones, should be decomposed by means of chloride of calcium, instead of the mineral acids which are usually employed for that purpose; carbonate of lime is formed, and chloride of ammonium remains in solution. After filtering or siphoning this liquid, he boils it for an hour, by which treatment any gaseous impurities are expelled. As soon as the liquid has cooled, it is agitated, first with sufficient hydrated oxide of iron to precipitate any sulphide of hydrogen that may still remain, and next with lime enough to saturate the whole of the combined hydrochloric acid; it is then distilled. By this treatment a tolerably pure solution is produced. It is to be observed, that when ammonia is prepared on the large scale, according to the method first described, the dry salt and lime are often mixed in the retort, and as operations are going to commence, a quantity of water is added for the purpose of slaking the lime, and preventing the mass adhering to the bottom of the retort; by this means so much heat is generated that considerable portions of the ammonia are driven over to the receivers, and thus fuel is economised. To prevent the residue hardening when the distillation is carried to dryness, it is customary to add a few spadefuls of common salt to the mass.

Liquid ammonia is of different strengths, according to the more or less complete saturation of water with the gas. As the quality of the solution depends mainly upon the available ammonia it contains, it is the duty of the manufacturer, as well as of the purchaser, to be acquainted with its amount. Specific gravity tables have been constructed by various chemists, for the purpose of ascertaining the value of ammoniacal solutions. In the formation of these tables a great many experiments were performed with liquids of various densities, for the purpose of arriving at their content of ammonia, and the amount corresponding to the intermediate gravities calculated according to the known properties of this alkali.

Of these, the results of DALTON, DAVY, and URE are generally preferred. According to DAVY, the appended table expresses the per centage in every hundred parts of liquid:—

Specific gravity of the liquid.	Per centage amount of ammonia.	Specific gravity of the liquid.	Per centage amount of ammonia.
0·8750	32·50	0·9435	14·53
·8875	29·25	·9476	13·46
·9000	26·00	·9513	12·40
·9054	25·37	·9545	11·56
·9166	22·07	·9573	10·85
·9255	19·54	·9597	10·17
·9326	17·52	·9619	9·60
·9385	15·88	·9692	9·50

DALTON attaches the boiling point and the volume of vapor in the mixture:—

Specific gravity.	Grains of ammonia in a hundred of the liquid.	Boiling points.	Volumes of gas in one volume of the solution.
0·850	35·3	26°	494
·860	32·6	38	456
·870	29·9	50	419
·880	27·3	62	382
·890	24·7	74	346
·900	22·2	86	311
·910	19·8	98	277
·920	17·4	110	244
·930	15·1	122	211
·940	12·8	134	180
·950	10·5	146	147
·960	8·3	158	116
·970	6·2	173	87
·980	4·1	187	57
·990	2·0	196	28

The following is the table of the strength of caustic ammonia compiled by Ure:—

Specific gravity.	Per cent of ammonia.	Specific gravity.	Per cent. of ammonia.
0·8914	27·940	0·9363	15·900
·8937	27·633	·9410	14·575
·8967	27·038	·9455	13·250
·8983	26·751	·9510	11·925
9000	26·500	·9564	10·600
·9045	25·175	·9614	9·275
·9090	23·850	·9662	7·950
·9133	22·525	·9716	6·625
·9177	21·200	·9768	5·500
·9227	19·875	·9828	3·975
·9275	18·550	·9887	2·650
·9320	17·225	·9945	1·325

The gravity may be taken by an ammoniometer, or spirit hydrometer, or in a specific gravity bottle, which, at the ordinary temperature and pressure, holds a thousand grains of water.

Prepared by the usual method, ammonia is liable to be impregnated with chloride of ammonium and sulphate of ammonia, which are sublimed, and carried over mechanically. They may be detected by neutralizing a portion of the alkaline solution with pure nitric acid, and testing the liquid, divided into two portions—one with chloride of barium, for sulphuric acid; and the other with nitrate of silver, for hydrochloric acid. A white precipitate, or milkiness, will in either case prove the presence of the acid sought. Should any lime or chloride of calcium be carried over, which is rarely the case if ordinary precautions have been taken, it may be detected by evaporating the solution to dryness, and heating the residue to dull redness for a short time, to expel any traces of ammoniacal salts that may be present; the impurities will remain. If volatile organic substances be mixed with the compounds from which the ammonia is derived, they may be carried over with the vapor and condensed in the receiver; such matters are detected by the brownish or dark color they communicate to the solution. These impurities may, for the most part, be removed by filtering through animal charcoal. The charcoal absorbs some of the ammonia, and should be washed occasionally with water to abstract it; the washings may afterwards be distilled.

Ammonia has been a prolific field for theoretical and experimental researches, and there is, perhaps, no compound in chemistry more interesting, or which acts a more important part. On this account its true composition ought to be thoroughly examined, for the manufacturer would be quite abroad in his calculations of produce and decompositions, unless good data could be laid before him for his instruction and guidance. The reader must not suppose that the minute details given in this work are superfluous; every ascertained fact is a step in progress; the very numerous and important discoveries of the last few years afford room for valuable deductions, so suggestive of further advancement, that they must sooner or later be found serviceable to industrial enterprise.

Regarding ammonia, the view taken of it, previous to more modern theories, assumed that its composition in all cases was three equivalents of hydrogen combined with one of nitrogen—$N\,H_3$; this being substantiated by the analysis of the dry gas, as indicated by the formula at page 178. When this compound united with water, or any of the hydracids, such as hydrochloric, hydrobromic, or hydriodic acid, the combination was presumed to have taken place without any change being effected in either body, and the formula, or symbolical representation of such compounds, was $N\,H_3\,H\,R$; R being any negative radical, such as oxygen, chlorine, bromine, or iodine. On the other hand, when $N\,H_3$ united with oxacids, the same isolation of the ammonia was preserved, and the formula of the salt, say the sulphate, which may be instanced as a type, ran thus:—$N\,H_3,\ H\,O,\ S\,O_3$. Now, as there exists an undoubted analogy between all the salts which ammonia forms, both with hydracids and the so-called oxacids, and the similar compounds which such acids form with the other alkalies, and some of the metals and metallic oxides, Berzelius, to establish a corresponding one in their symbolical representation, assumed that ammonia was the oxide of a hypothetical metal, *ammonium*, the symbol of which was $N\,H_4$, analogous to the other metals. The fact that the compound, ammonia, in the former view, required in every instance an equivalent of hydrogen in the acid, or water, to form a corresponding salt or hydrate, seemed to justify the hypothesis of the great Swedish chemist so far that his view has been almost universally adopted; for—

$$\underbrace{N\,H_3,\ H\,O}_{\text{Ammonia of the former view.}} = \underbrace{N\,H_4\,O}_{\text{Ammonia of the Berzelian view.}}$$

And in like manner—

$$\underbrace{N\,H_3,\ H\,Cl}_{\text{Hydrochlorate of ammonia by the old view.}} = \underbrace{N\,H_4\,Cl}_{\text{Chloride of ammonium, by the Berzelian theory.}}$$

In the same manner the composition of the salts formed with oxygen acids, such as the sulphate, was represented in the old nomenclature as $N\,H_3,\ H\,O,\ S\,O_3$, while in the Berzelian it is $N\,H_4\,O,\ S\,O_3$. In this way was introduced a happy conformity in the formulæ, corresponding to that analogy in properties and appearance existing between the salts of ammonia and those of other metals similarly constituted.

But if it be assumed with Berzelius, that the metal ammonium exists, and that, as previously explained, the hydrogen of the acid associated with the $N\,H_3$ of the old view, is necessarily abstracted by the $N\,H_3$ to constitute the supposed metal—then, to support this assumption, another must be admitted which is highly improbable, namely, that the affinity which the radicals of the hydracids manifest for hydrogen is less powerful than that of the gaseous compound $N\,H_3$. And, again, if it be supposed that the compound of hydrogen and nitrogen, in the proportion of four of the former to one of the latter, is a metal, on account of the relations which seem to bind it to the other metals, and their combination with other compounds—by the same argument it must be admitted that $P\,H_4$ is also a metal, for the terhydride of phosphorus PH_3 reacts exactly like $N\,H_3$ towards hydracids; thus, when influenced by hydrochloric or any such acid, instead of $P\,H_3,\ H\,Cl$, it is by the Berzelian demonstration $PH_4\,Cl$, constituting this compound, $P\,H_4$, a metal analogous to ammonium, NH_4, or to potassium, K, or any such metal.

Kane, in his investigation of the ammoniacal compounds, regards the dry gas, and in fact all the ammoniacal bodies, as springing from a radical, *amidogen*, whose formula is NH_2, having the closest analogy to oxygen and chlorine. According to this view, dry ammoniacal gas is represented as an amide of hydrogen—

$$\underbrace{NH_3}_{\text{Ammoniacal gas.}} = \underbrace{NH_2 + H}_{\text{Amide of hydrogen.}} \textit{ or } H + NH_2$$

Ammonia, according to the chemist above-mentioned, possesses the property of a feeble base, and is capable of uniting with dry hydracids, as chloride of hydrogen —hydrochloric acid—forming chloramide of hydrogen, HNH_2, HCl—chloride of ammonium. It also enters into direct combination with dry oxacids, but it does not then form the proper ammoniacal salts, which all contain an *essential* atom of water. NH_4 of the Berzelian nomenclature is described by **Kane** as a subamide of hydrogen, $NH_2 + 2H$, or H_2NH_2; and this compound with oxygen he regards as an oxamide of hydrogen, H_2NH_2O, or HNH_2, HO.

Another peculiarity of the bodies which amide of hydrogen forms with acids, is their isomorphism with those of the magnesian family of compounds, consequently requiring two equivalents of base; thus, NH_4O, SO_3, is regarded as HNH_2, HO, SO_3, and here the HNH_2, HO, is isomorphous with potassa and soda.

Each of these theories asserts a claim to probability, and might be regarded as a true exponent of the behavior of the compounds in question; but none of them will obviate all objections. The generality of the chemists concur in ascribing the preference to the Berzelian view: first, because it is more simple, and as regards the combining link which it forms in the series of analogous compounds of non-metallic bodies, the formulæ of the ammonia series of salts are more in harmony on this hypothesis than on any other. At the same time it must be borne in mind, that although the chemical relations of the ammonia salts confirm the ammonium theory, still, neither ammonium nor its oxide is capable of existing uncombined.

Ammonia unites with all acids, forming salts. Those manufactured to any extent are, the chloride, the sesquicarbonate, the sulphate, and the acetate.

Chloride of Ammonium, or Sal-Ammoniac.—The manufacture of chloride of ammonium was first practised by the Arabians, although it has been attributed to the Egyptians. The term *sal-ammoniacus*, which is very ancient, has been applied by modern historical writers to the substance which is now understood by that name; but whether the ancients, at the period in which this term was used, applied it to our chloride of ammonium, is a doubtful point. **Pliny** and his cotemporaries were unacquainted with sublimation in any shape; and it is a fact, that even the process of lixiviating earths, or crystallizing saline substances from their solutions, was so ill understood, that the native compounds, however impure, were employed in the manufacture of inks, colors, *et cetera*. From the many evidences and arguments adduced by **Beckmann**, it is almost certain that the sal-ammoniacus of the ancients was no other than common *rock salt*. Indeed, the uses to which it is stated the sal-ammoniacus was then applied, leaves no doubt that the chloride of ammonium was not meant. The Arabian writers are the first who transmit accounts of the true sal-ammoniacus. **Geber** furnishes a prescription for its purification by sublimation, and another for its preparation; still **Beckmann** throws a doubt upon the authenticity of these statements, as to their being **Geber's**, on account of the various additions which were introduced into his works by more modern writers.

Sal-ammoniacus was an article of trade about the year 1410; but the purposes to which it was applied, or the mode of its preparation in Egypt at that period, have not been recorded. In the sixteenth century many of its properties were known, particularly its behavior with nitric acid by which aqua-regia is formed.

The younger **Geoffroy** was the first who showed that it consisted of hydrochloric acid and volatile alkali, and that it could therefore be produced in Europe by sublimation. An account of the sal-ammoniac—chloride of ammonium—manufactories at Damayer, in the Delta, was given, in 1720, by a Jesuit named **Sicard**. It is uncertain at what period the manufacture became general in Europe. Large manufactories of this article were instituted in Scotland from the year 1750 to 1756. Chloride of ammonium was discovered in the mineral products of volcanic districts, so early as the fifteenth century. It is generally met with, sublimed among other volatile bodies, in the fissures of lava, particularly at Vesuvius, Etna, in the Island of Volcano, and at the Solfatara, near Naples. Small quantities of it have been found in the vicinity of ignited coal-fields, as at St. Etienne in France, in Scotland, and at Newcastle. A variety, possessing a greyish-white color, of a conchoidal fracture, has been mentioned as occurring in Bucharia. The native salt is generally massive, has a fibrous texture, is sometimes plumous, in crusts, and in minute octahedral crystals; its color, when pure, is white, grey, or yellow; transparent or opaque; externally dull or glistening, and internally shining or vitreous. The salt has a pungent and saline taste, is readily soluble in water, but does not attract moisture on exposure to the air; it completely volatilizes in white fumes at a high temperature, and emits, when triturated with lime, a strong ammoniacal odor.

Two samples, from Vesuvius and Bucharia, yielded to **Klaproth** the following results:—

	Vesuvius.	Bucharia.
Chloride of ammonium,	99·5	97·5
Sulphate of ammonia,	0·5	2·5
	100·0	100·0

Chloride of ammonium is prepared by the chemist simply by neutralizing pure ammonia with hydrochloric acid, or by transmitting a stream of the gas into a solution of this acid till saturated, and then evaporating and crystallizing the salt. The properties of the chloride, in a chemical point of view, are not very characteristic, though in a manufacturing light the compound is highly important; these, however, will be mentioned after the reader becomes familiar with the chief methods followed in its preparation on a large scale. In Egypt, which undoubtedly was the great seat for its manufacture from the thirteenth to the middle of the seventeenth century, and whence all the European markets were supplied, the following is the process by which they obtain it.

The great source is the urine and dung of the camel, which, as URE relates, are dried, by plastering them upon the walls, and burned instead of other fuel, which is very scarce in that country. A fire of this material evolves a thick smoke charged with chloride of ammonium, part of which is condensed in the soot; and on this account the latter is carefully collected throughout the country, particularly in the Delta district, and brought to the sal-ammoniac factories, for the purpose of distillation. The first accurate account of the manner of manufacturing the salt in Egypt, was transmitted thence to Europe by LEMERE, French Consul at Cairo, in 1770. The soot was put into large round glass bottles, which were externally coated with loam, in order that they might bear the heat better; these bottles were ranged in a long ridge or terrace, in such a way that only the necks were exposed to the air, while the flue from the furnace circulated freely round each of the bottles. These bottles, or globes, were generally a foot and a half in diameter, and the necks about two inches long. Forty pounds of soot formed the charge, filling each of them to within four inches of the neck; and from this weight of material about six pounds of the salt were obtained. A fire, made of dry camel's dung, heated the range of bottles; on the second day, when the bottles became heated, the salt commenced subliming, and much care then became necessary on the part of the attendant to keep their necks free for the passage of the uncondensed vapors. Towards the conclusion of the operation, the fire was urged to bring the globes to incipient redness, that the last portions of the salt might be disengaged. At the end of the third day the fire was extinguished, and as soon as the globes cooled they were taken out, broken, and the cake of salt abstracted, which in this form was exported to Europe. On breaking the bottles, a nucleus of the salt was found surrounded by a fixed pulverulent substance, which was taken out and mixed with fresh portions of the soot in the succeeding operation. Evidently, considerable quantities of the salt were lost by this mode of preparation.

GEOFFROY relates that chloride of ammonium was imported from India, where it was manufactured in much larger quantities than in Egypt. It assumed in the subliming vessel the form of a sugar loaf, and weighed about fifteen pounds. These loaves were composed of three distinct layers; the upper of each was impure, and was generally cut off. Egyptian and Indian sal-ammoniac was a dull, spongy, and greyish mass, considerably inferior to the compound now made; nevertheless, on account of its scarcity, it commanded a price more than six times that of the *pure* article at the present time.

Before the introduction of gas-lighting, the chloride of ammonium made in Europe was obtained from offal or the refuse cake of oil presses, either by allowing it to undergo the putrefactive fermentation, or submitting it at once to destructive distillation; the latter course was adopted in Germany. In this country, soot deposited from pit coal was once employed to yield the salt. The distillation of pit coal affords considerable quantities. The first factory of any extent which was formed in France for the preparation of ammoniacal products from this substance, was under the superintendence of BEAUMÉ; it failed after twenty-seven years' standing, leaving the shareholders sufferers to the amount of four hundred thousand francs—another, among many instances on record, of a purely theoretical chemist not being always the fittest person to conduct a manufacturing operation.

At present the salt is extensively made from bones, which are distilled in iron retorts, for the preparation of charcoal for depurating purposes. The accompanying drawings—Figs. 106, 107, and 108—represent the furnace used by the French for distilling bones, and obtaining the ammoniacal compounds and the oil from them.

Fig. 106 is a longitudinal vertical section of the retort, A A, for holding the bones, showing its position in the dome of brick which encloses the fire, B. The flue, after passing round the retort, is shown to advance to the front of the furnace, as at D, before it returns by the arch, E, and enters the chimney, J, at the back. The pipe, G, emerging from the far end of the retort, enters the cylinder, H—Fig. 108—into which it conducts all the eliminated products of the distillation.

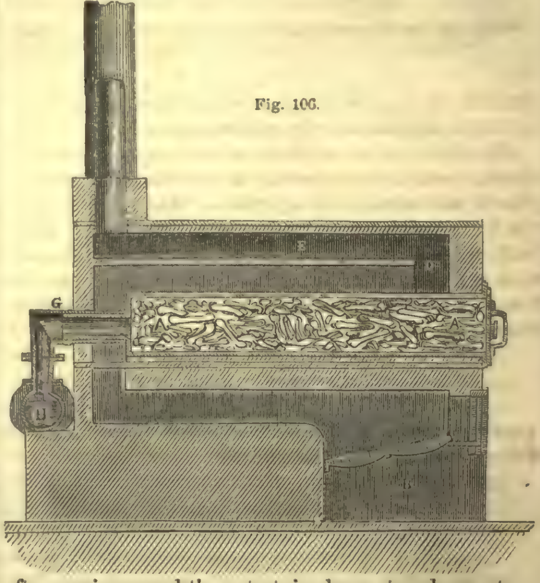


Fig. 106.

Fig. 107 is a vertical section of the series of retorts and furnaces, made at right angles with Fig. 102, and parallel to the front elevation. A A A are the retorts, and B B B the furnaces, placed immediately under, though not in contact with them. This figure shows more clearly the circuitous passage of the flame and heated strata of vapor from the fires, B, surrounding the retorts laterally at C C, and horizontally at D D, above, as well as at the fireplace below. When the heated air reaches the front of the chambers, D, it returns, as seen in Fig. 106, by the space, E, to the chimney, J. On the right is shown the safety-valve, K, by which air is admitted into the apparatus when the distillation of a charge has been finished; and at the opposite side is seen a portion of the pipe which conducts the uncondensed vapors to the refrigerator.

Fig. 107.

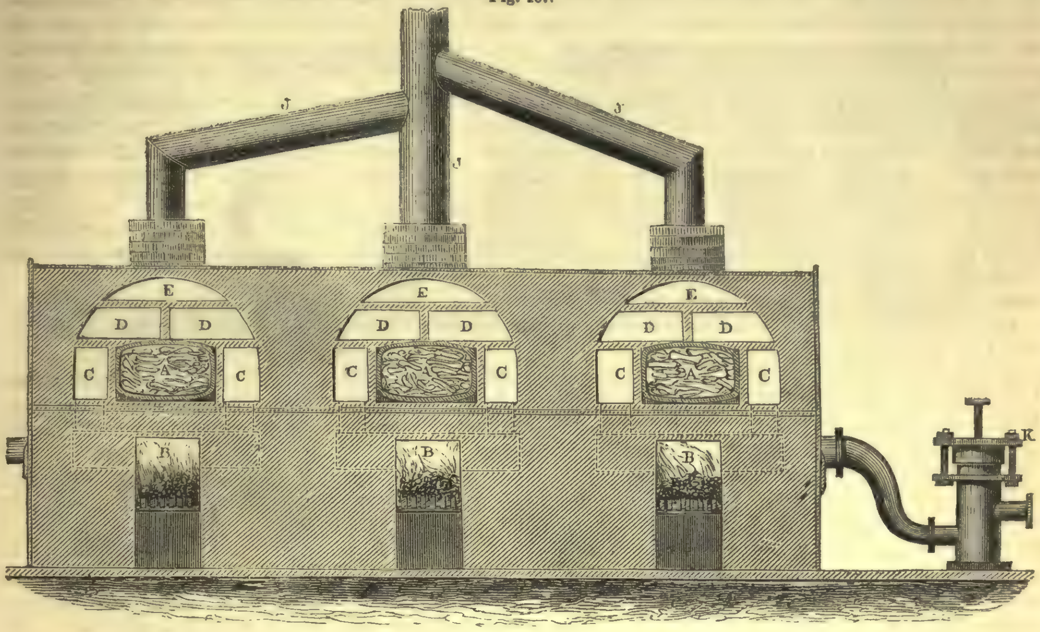


Fig. 108 exhibits a horizontal section of the flues surrounding the retorts, with a view of the condensing pipes from above. In this figure the flues are seen to rise from the canals, C C, to the chambers, D D, at the back, through *f f*, and from D they pass off similarly to E, at the front, as in Fig. 106. The condensing pipes, H and I I, are seen vertically; the latter are rather inclined, and enclose the entrance pipe, while the surrounding space is kept replenished with cold water, which enters at the lower, and is discharged at the upper pipe, as it becomes warm. This arrangement is shown in the section, K. From the end of the last refrigerator, the condensed products are discharged into a suitable receiver, where the oil collects at the top in a layer, and is skimmed off, leaving the ammoniacal liquor, to which the appropriate acid, whether hydrochloric or sulphuric, is added in proper proportion, till the solution is neutralized; the liquid is then pumped, or otherwise transferred, to the evaporating pans to be concentrated.

Fig. 108.

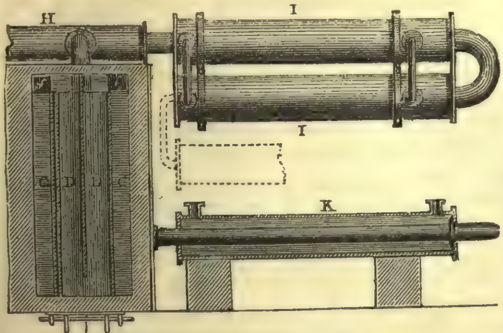
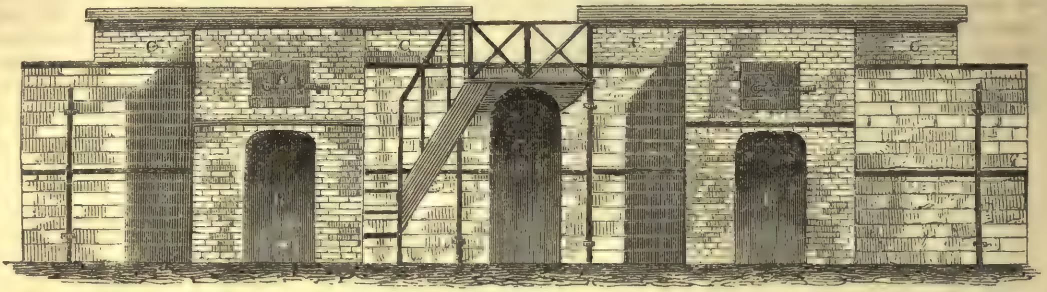


Fig. 109 represents a range of such evaporating pans as are used in France. A A are the fires, B B the ash-pits, and C C C C the evaporating pans, which are about nine feet square, and eighteen inches in depth, and are formed of sheet-lead; their front rests upon a dome of firebrick, and the remainder is supported by cast-iron plates, resting upon supports of brickwork, which serve to disseminate the heat of the furnace under the bottom of the pan.

In Fig. 110, A shows the firebars of the furnace, and C the course of the flame, interrupted repeatedly by the upright brick walls, serving the double purpose of equalizing the heat under the pan, and of supporting the iron plates on which it is laid.

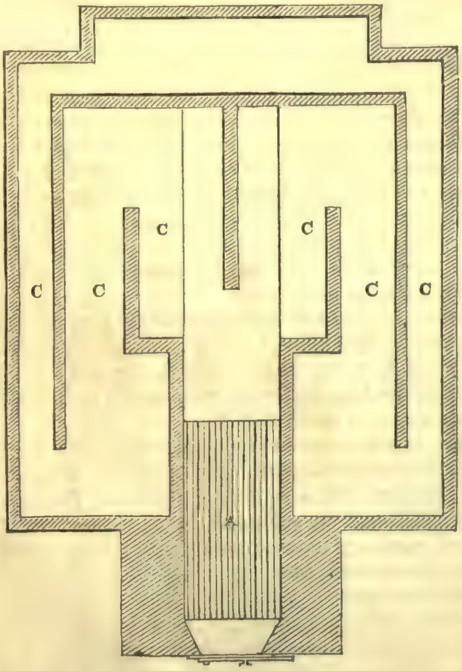
When impurities pass off in large quantities from the distillation of the bones, and are condensed in the liquid, they are almost entirely separated in the tank on the addition of the acid; and, before evaporation, it is found necessary to remove them completely, which is most conveniently done by a process of filtration. The filters consist of a long wooden box lined with sheet-lead, and having an outlet pipe at its lowest end, for the purpose of drawing off the liquid into the receiver. A frame, corresponding to the shape of the vessel, is adjusted by means of wedges, perfectly horizontal, and within an inch of its bottom. Round bars of wood are fixed lengthways in this frame, and upon it a canvas or stout linen cloth is drawn tightly, being secured at the sides and ends of the frame by means of tacks. On passing the liquid through this cloth, most of the solid impurities are withheld; and in order that there may be as little of these as possible retained in the liquid, it is returned by means of a pump from the tank two or three times, to undergo fresh filtrations. A common receiver, placed below the others, may be made to communicate with any of the filters by means of intermediate stopcocks.

Fig. 109



When the liquid is sufficiently clear, it is pumped up into the evaporating pans just described, and concentrated. As soon as the liquid acquires a certain gravity, it is drawn off to the crystallizing pans. These are wooden boxes, lined with sheet-lead, and are of various dimensions, from six to ten feet in length, three to six feet in breadth, and one and a half to three in depth. When the mass of salt is crystallized, the crystallizers can be inclined towards either side, in order to drain off all the mother liquor, which is received in an appropriate cistern, and is afterwards pumped into the evaporating pans, to be concentrated with another portion of the ammoniacal liquor; the pump employed is made of lead, hardened with antimony and tin.

Fig. 110.



When the crystallized chloride of ammonium is well drained, it is submitted to the subliming process. The arrangement used for this purpose is represented in the annexed woodcuts—Figs. 111 and 112.

The sublimers are earthen or stoneware pots, placed in two ranks, upon the arch of the flue, passing from the fire, A, which heats them. The longitudinal section of the furnace—Fig. 111—shows one row of these pots. Under the pots, represented in the engraving by D, circular openings from the main flue are made in the arch of brickwork, by which the heated vapor and flame are made to circulate around them, and thus they become hot enough to sublime the salt. The bottles, or pots, are encased in the furnace to their necks, as seen in the front view and transverse section in Fig. 112; and a plate of iron, with indentations corresponding to the size of the bottles, runs along between the two lines, as shown at B B. The space between this plate and the dome on which the bottles rest, is left for the free circulation of the flame and heated air of the furnace, which effects the sublimation. To economize fuel an evaporating pan is often appended to the subliming furnace; and the heated air from the chamber of sublimation, as it passes to the chimney, is made to run along a number of square openings, over which the evaporating pan is supported by cast-iron plates, and at the end of this pan they unite into one flue, just before entering the chimney.

The salt is generally dried in this manner previous to being sublimed.

The pots are of variable dimensions, but those most frequently employed are about eighteen inches in height in the body, and the caps about ten or twelve inches, with a breadth of sixteen inches at the widest part. The annexed numbers show the produce of a large French manufactory of ammonia and its salts, from the distillation of bones and other matters. The materials were—

46,754	tons	of bones of various kinds,
30	"	silk waste and old leather,
11½	"	sulphuric acid,
80	"	chloride of sodium, and
2¾	"	sulphate of lime;

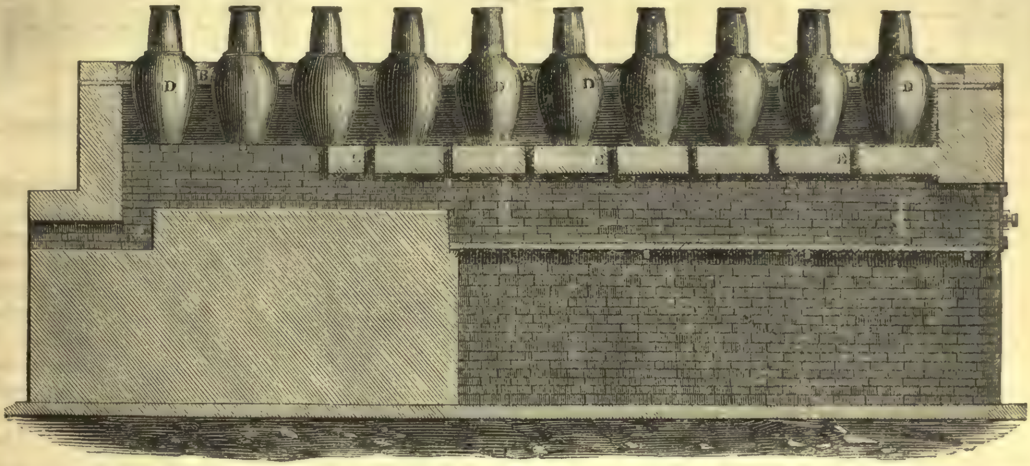
and the produce—

2,400	tons	of animal charcoal,
44	"	chloride of ammonium,
100	"	sulphate of soda,
4	"	liquor ammonia, and
25	"	sulphate of ammonia.

In this manufactory, the sulphate of ammonia is obtained by treating the ammoniacal liquor—which contains chiefly carbonate of ammonia—with sulphate of lime, when double decomposition takes place, carbonate of lime and sulphate of ammonia being formed. The latter remains in solution, and may be obtained by filtration from the lime precipitate, and subsequent evaporation of the solution in the manner indicated by the preceding sketches of the apparatus employed.

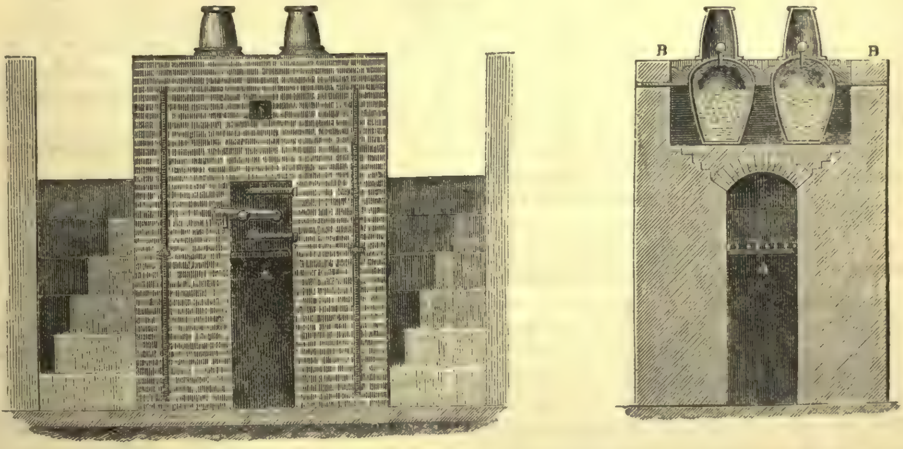
The chloride is prepared either by adding the hydrochloric acid at once to the crude liquor, and evaporating it, or by converting the ammonia into the sulphate, and decomposing this salt by chloride of sodium, which causes the formation of sulphate of soda and chloride of ammonium; the latter is separated by sublimation. Occasionally, the chloride of manganesium, from the refuse liquor of chlorine stills, is used to decompose the crude carbonate of the alkali; the carbonate of manganese precipitates, and is separated by filtration, and the solution of the ammonia salt is treated as in the other instances.—*Pharmaceutical Journal.*

Fig. 111.



Ure states, that when offals are used to procure ammonia by their destructive distillation, they should not be heated beyond the ordinary temperature required to disengage their ammoniacal compounds, in order that the charcoal which such matters yield may be available in the manufacture of prussian blue. According to this chemist, the density of the liquor from the distillation of the bones and other substances, when mixed, is 1·060; and when the chloride of ammonium is prepared by means of sulphate of lime and common salt, the following is the method pursued:—

Fig. 112.



The crude carbonate of ammonia is decomposed by passing it through a bed of sulphate of lime, three or four inches thick, which is spread out upon filters. The liquor may be poured upon the gypsum by means of a pump, but it should never stand higher than from one to two inches above the surface of the coarsely ground salt, and to prevent the dissipation of any of the volatile alkali, the vessel should be closely covered over with boards. When the liquor has passed through the first filter, it must be pumped upon the second; or the filters being in a terrace form, the liquor from the first may flow down upon the second, thence upon a third, and so on in succession. The last filter ought to be composed of nearly fresh gypsum, so as to insure the thorough conversion of the carbonate into sulphate. The resulting layers of carbonate of lime should be washed with a little water, in order to extract the sulphate of ammonia interposed among their particles. The ammoniacal liquor thus obtained must be completely saturated, by adding the requisite quantity of sulphuric acid; even a slight excess of the acid can do no harm. It is then to be evaporated, and the oil, which is generally carried off in the ammoniacal liquor in combination with the alkali, and is set free by the slight excess of acid, must be skimmed off in the course of the concentration. When the liquid sulphate has acquired the density of 1·160, chloride of sodium should be added with constant stirring, until the whole quantity required for the double decomposition is introduced into the boiler. The liquid portion must now be drawn off by a siphon into a somewhat deep reservoir, where the impurities are allowed to subside; it is then evaporated by boiling, till the sulphate of soda falls down in granular crystals—as the result of the mutual action of the sulphate of ammonia and chloride of ammonium, thus:—

$$\underbrace{NH_4OSO_3}_{\text{Sulphate of ammonia.}} + \underbrace{NaCl}_{\text{Chloride of sodium.}} = \underbrace{NH_4Cl}_{\text{Chloride of ammonium.}} + \underbrace{NaOSO_3}_{\text{Sulphate of soda.}},$$

while the chloride of ammonium, being more soluble, remains in the liquid. During the precipitation of the crystallized sulphate of soda, the whole of the liquid must be agitated by wooden paddles, or spatulas, the precipitate being in the intervals removed to the colder part of the pan; thence it is taken by means of copper rakes and shovels, and thrown upon the draining copper placed near the edges of the pan. The drained sulphate of soda must be afterwards washed with a little cold water, to extract all the adhering chloride of ammonium. The liquor thus freed from the greater part of the sulphate, when sufficiently concentrated, is to be drawn off by a leaden siphon into the crystallizers, where, at the end of twenty or thirty hours, it affords an abundant crop of crystals of chloride of ammonium. The mother water may then be run off from the crystallizers, which should be placed in an oblique position to drain the salt; when this is done, the crystals must be washed, first with a weak solution of chloride of ammonium, and next with a small quantity of water. The mass of crystals is then desiccated in a furnace, where all the moisture is removed, after which it is put into the earthen subliming bottles by means of a funnel, and rammed down tightly; the heads are then placed securely on, and heat cautiously applied, so as to effect the sublimation of the pure salt from the bottom to the upper part of the bottle, and the vent hole, as shown in the section of the bottles in the foregoing Fig. 112, must be cleared from time to time, by means of a long steel skewer, to prevent the risk of choking, or consequent bursting; in spite of these precautions it happens, however, that several of the bottles crack in almost every operation.—*Ure.*

The preceding method of sublimation is never followed in the manufactories of ammoniacal salts in this kingdom, though a process somewhat analogous is pursued in Glasgow, where the salt is expelled from cast-iron pots, lined with fireproof tiles; the vapors are received and condensed in a hollow globular head of green glass, with which each of the iron pots is capped. The chloride of ammonium thus formed is sold in hollow spherical masses, corresponding in shape to the head of the vessel, being previously freed from any adhering impurities by mechanical means. The residuary matter left in the pots, which still retains some of the salt, is lixiviated, and the liquor worked up in another operation.

Ammoniacal salts are now more extensively produced from the crude liquor of gas-works than from any other source; this has dispensed with the disagreeable necessity of collecting and storing putrid urine for the purpose—a practice formerly extensively followed.

In a large Glasgow factory, where upwards of seventy thousand gallons of gas liquor are consumed weekly, it undergoes the following treatment:—The liquor is first rectified by distillation from a waggon-shaped wrought-iron boiler, into a square cistern of iron lined with lead. Forty-five hundred pounds of sulphuric acid, of specific gravity 1·625, are then added slowly to the somewhat concentrated distilled ammoniacal water. The produce is about twenty-four hundred gallons of solution of sulphate of ammonia, slightly acidulated, of specific gravity 1·150, being of such strength as to deposit a few crystals upon the sides of the leaden-lined iron tank, in which the saline combination is made. This liquid is decomposed with common salt to obtain the chloride.

The following routine is practised at the factory of Messrs. Kurtz, Cropper, and Co., in Liverpool, who kindly laid the whole of the several processes open to the Editor's inspection. The gas-works supplying the crude liquor are situated on each side of the factory, at the distance of three quarters of a mile; a communication is opened by means of a canal, on the banks of which are the two establishments. Flats, constructed of sheet-iron, and divided into compartments of known capacity, convey the ammoniacal liquor to the factory. As soon as the flat comes alongside, the gas liquor is drawn off by a hose, eight or ten yards long, to a receiver placed within the walls of the premises; thence it flows through a conduit pipe to large subterranean cisterns, capable of holding a hundred thousand gallons or more, which are situated nearly in the middle of the factory, and adjacent to large tuns, each capable of holding fourteen to eighteen thousand gallons. Fig. 113 shows the front of these tuns, and the general apparatus appended to them.

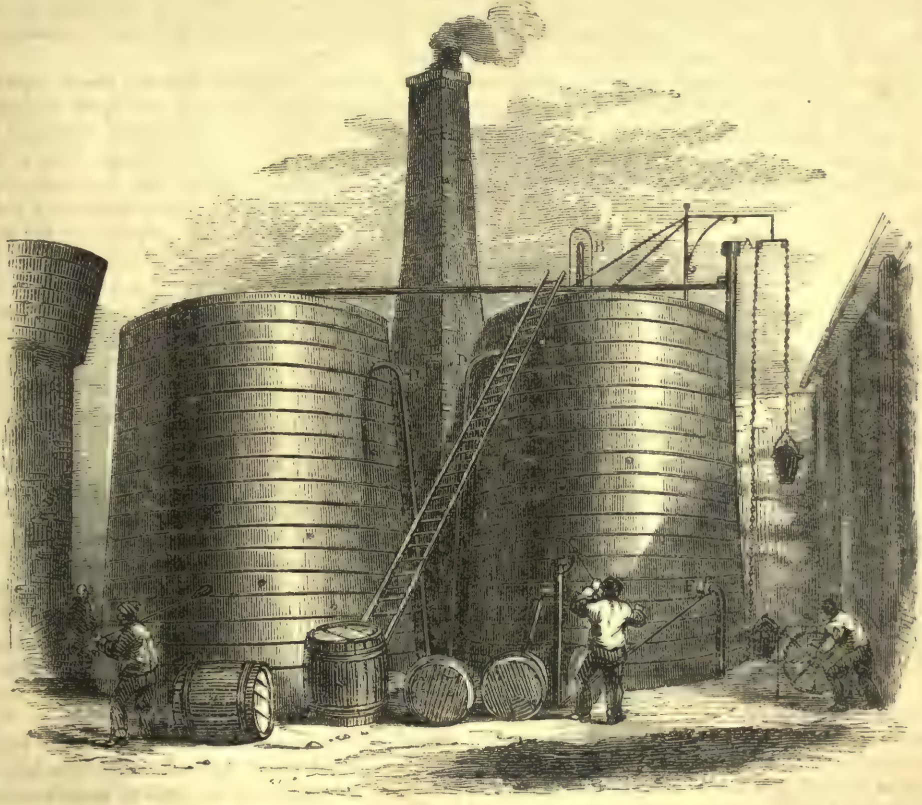
By means of a pump, A, connected with the reservoirs, the crude liquor is raised into the tuns; and after a considerable quantity has been pumped, strong hydrochloric acid, in the proportion of one and a half or two pounds to the gallon of the crude liquor, is introduced by the aid of a pulley, or crane, and gutta percha carboys, as shown in the engraving. Metallic pumps cannot be used, on account of the corrosive action of the acid, and even pumps made of gutta percha do not answer.

When the proper quantity of acid has been added, both liquors are intimately mixed by an agitater placed within the tuns, and worked by the same machinery as the pump in connection with the subterranean reservoir; this machinery, however, is not seen in the figure. Disagreeable vapors, in large quantity, consisting of sulphide of hydrogen and other injurious gases, are disengaged during the saturation of the liquid; these are not permitted to escape into the atmosphere, till they first traverse the fire belonging to the steam-engine, being conducted thither by the pipes, D D.

The liquor in the tun should have a faint but distinct acid reaction. The hydrochloric acid, besides uniting with the ammonia, causes the tar and other bodies, held mechanically and in solution, to separate and subside to the bottom of the tun in the course of three or four days, leaving the supernatant liquor much purer, but still deeply colored.

It is then drawn off at several outlets, shown by the dots in the sides of the tuns, but which are kept plugged during the previous part of the operation, and conducted by small sluices or troughs, appended to them when required, to the store vats and the several concentrating pans, all of which are constructed of cast-iron plates riveted together. The deposits of tar and other matters are drawn off at the lower openings, or by the tap in the pipe, E, when they have accumulated to that elevation, though this rarely happens, to a well or reservoir adjoining, whence they are pumped into barrels, to be carried to another department of the factory, as shown in the sketch. When there is a superabundance of crude ammonia liquor, it is conducted by the pipe, E, to the sulphate of ammonia works in this establishment.

Fig. 113.

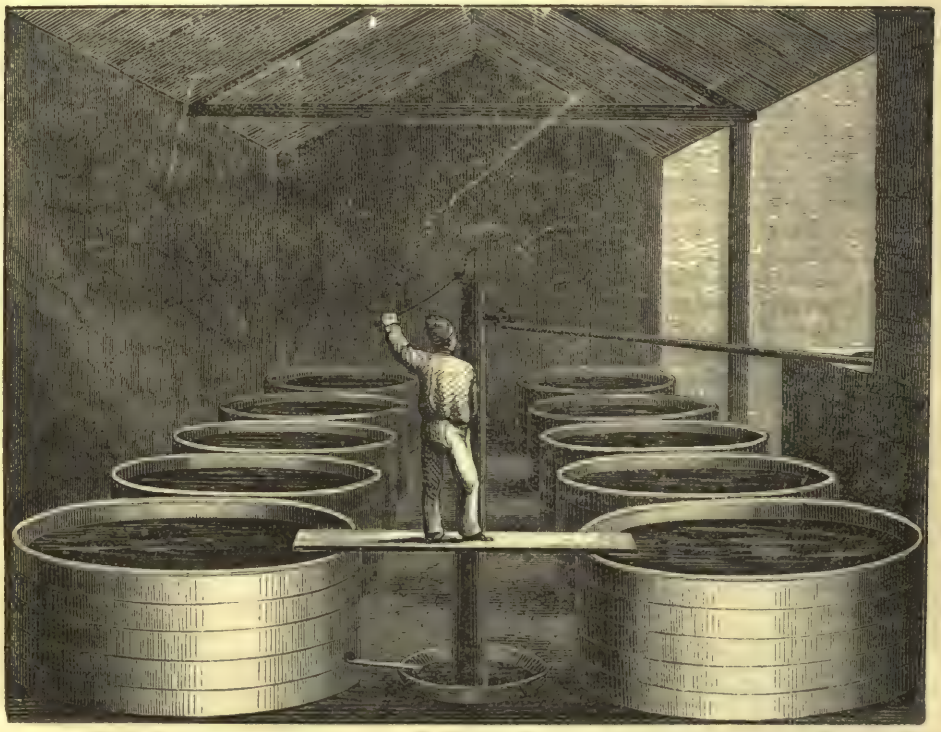


The evaporators are square, rectangular, or circular cast-iron vats, capable of holding from eight to fifteen hundred gallons; some of them are partly incased in brickwork. Heat is applied usually by a fire, the flue of which takes a sinuous course beneath the lining of brickwork on which the pan rests. During the concentration, considerable quantities of petroleum and other impurities, not deposited in the tun, separate, and are immediately removed by skimming. The liquor, which marked only 5° Twaddle previous to being submitted to the action of heat in the pans, is of 50° Twaddle, or 1·25 specific gravity, when transferred to the crystallizers. As the solution is slightly acid when drawn over from the mixing tun, this acidity becomes more distinct as the excess of water is dissipated, and might be productive of inconvenience if it were not neutralized from time to time by the addition of quicklime or chalk in small quantities; but a more economical way would be to saturate it with ammoniacal liquor. The neutralizing is advantageous likewise in precipitating any sesquioxide of iron which might prove deleterious in the subsequent operations. The liquid being brought to the gravity 1·25, as above noted, is run off to the crystallizers, which are for the most part circular tubs, from seven to eight feet in diameter and two to three in depth; they are partly imbedded in, or rest upon, the ground.

Fig. 114 is a view of a range of these vessels; they are so placed that the concentrated solution of the chloride of ammonium can be drawn into them from the boilers.

According to the state of the weather, the salt crystallizes out in four or six days. In crystallizing the chloride of ammonium, it is not desirable to have large and well-defined crystals, especially when the salt is afterwards submitted to sublimation; the process becomes much more difficult with such crystals than with the more divided salt, on account of the cohesiveness of the former, which has to be overcome by the comparatively small surface exposed to the heat. On the contrary, when small crystals are submitted to the heat, the cohesion offers scarcely any resistance, and a greater surface is exposed, so that, in this instance, the sublimation proceeds rapidly. Hence, when the solution of the salt is set to solidify, the crystals which form on the top, as well as those on the sides and bottom of the vessels, are broken by agitating the liquor every six or eight hours, according to its state of concentration. Eight or ten days are allowed for the salt to crystallize, after which the mother liquor is removed through an opening at the bottom to a well sunk in the ground, whence it is again pumped into the concentrating pans as shown.

Fig. 114.



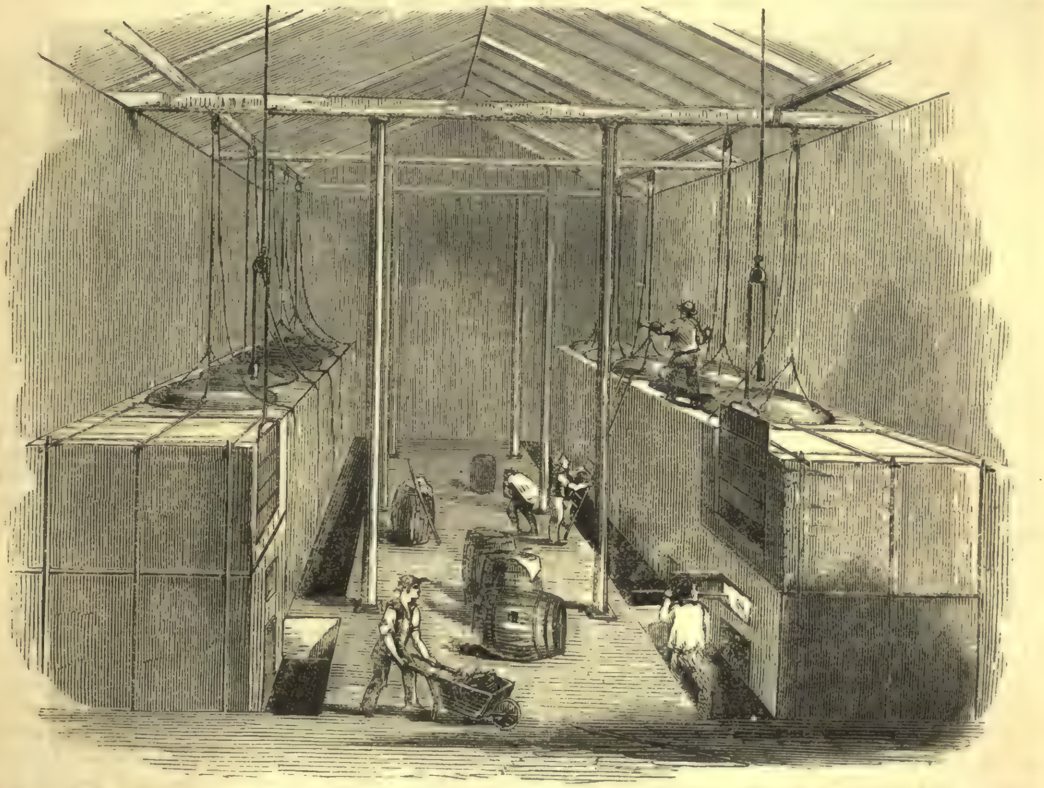
Chloride of ammonium, as obtained by the first crystallization, is a blackish salt, interspersed with moderately large cubical crystals. The blackness arises from tarry, oleaginous, and other impurities, mechanically held in the liquor, which fall down, more or less, with the crystals; the chloride also contains mechanical water, some sulphates and hyposulphites, all of which tend to deteriorate the quality of the article, if the mass were submitted to sublimation in their presence. To get rid of these impurities as much as possible, the well-drained crystals are introduced into the bed of a drying furnace, covered with a cast-iron plate, the whole surmounted with a dome of brickwork, and erected near the sublimers. This drying bed is heated by a fire placed under it, the flue of which is brought several times into such a position that the plate is within its influence. The charge introduced into this chamber, which is between six and eight feet in length and about four feet in breadth, is sufficient to cover the entire plate to the depth of four inches. The heat should never be raised to a high degree, lest some of the salt be volatilized. When all the water and free acids are removed, and the tarry impurities for the most part decomposed, the greyish-white mass is drawn out and supplied to the sublimers, where the salt is eliminated from the foreign impurities.

The sublimers are circular spaces, constructed in a mound of brickwork, walled interiorly with firebrick, and lined with cast-iron plates, round the sides of which the flue from the fire underneath coils, after it passes from the bottom. These subliming vessels are capped by a cast-iron cover, somewhat of the shape of a flat-bottomed watch-glass. They are from three to nine feet in diameter, and their concavities about two; they weigh from ten to thirty hundredweight. Three rings, at equal distances, allow of their being lifted off by means of a pulley and chains which can be attached to these rings. When in active operation, a pressure of from three to four pounds per square inch bears against them, which requires their being firmly fixed to the flat rim of the body of the subliming vessel. In the centre of some of these is a small hole, which is closed by an iron spindle; this is removed from time to time, to allow any elastic uncondensable products to escape.

The annexed woodcut—Fig. 115—is a view of these sublimers and drying furnaces. They are heated by the fires, which are briskly kept up till the sublimers and their surroundings attain a sufficient degree of heat; they are then slackened, and maintained at a mean temperature.

Much of the success of the sublimation depends upon the regulation of the heat; too high a temperature will not answer, for then large quantities of empyreumatic bodies would be disengaged by the further decomposition of tarry matters, which would in some measure interfere with the operation, and prevent the salt solidifying; and should the temperature be under the true medium, there will be a looseness of texture and an opacity in the salt greatly against its value in the market. As the attendant cannot conveniently ascertain the most suitable temperature, any scientific directions for that purpose would be lost upon him; he may, however, by simple means, discover what costly pyrometers might fail to demonstrate in his hands. A few drops of water should readily boil on the cover of the sublimer, and be pretty soon dissipated in vapor; but the evaporation should not be so rapid as to indicate that the heat was approaching to redness; neither ought the heat to be so far raised as to cause a drop of liquor to dance about, out of contact with the iron. A short practice and attentive observation will enable the operator to govern the fire with effect. The top of the sublimer is invariably covered with some non-conducting material, that the caloric may be economized as much as possible.

Fig. 115



As the size of the sublimers varies, as above stated, so also does the amount of the charges, being from half to two or two and a half tons weight of the salt; the former is sufficient for the sublimers of three feet diameter, and the latter for those which are nine feet; sublimers of five feet diameter generally require from fifteen to eighteen hundredweight of the salt.

In consequence of chloride of ammonium still retaining some traces of water, even after the torrefaction in the drying furnace, and as it is liable to absorb a little from the atmosphere while the workmen are transferring it to the sublimers, the first coating of the salt in contact with the cover is always brownish. Several reasons might be assigned for such an effect: firstly, the moisture condensing upon the head, and softening any trace of oxide, would cause it to sink into the layer of salt that deposits thereon; secondly, decomposition of any resinous matters not completely destroyed in the drying furnace, whereby oily vapors would be liberated; and lastly, the presence of the sesquichloride or protochloride of iron. The effect of the latter, however, is not immediately on the first layer, but more generally afterwards, when a higher temperature pervades the whole.

The termination of the sublimation takes place in from five to nine days; but it is customary to raise the caps every week, the fire being checked for some hours previous to this. The salt is not completely sublimed, because the temperature required to expel the whole would cause the decomposition of the carbonaceous impurities, and emit vapors which would destroy in a great measure the beauty of the article. When a low heat is communicated, or the compound consigned to the subliming furnaces is impure, the chloride does not assume that compactness of grain which conduces to its transparency, but forms a kind of effloresced mass, though retaining the fibrous construction of the better quality. When the sublimation has reached as far as is desirable, the fire, as already stated, is allowed to go out, that the apparatus may cool; the cover is then removed by means of the tackle before noted, and there is found in the interior a hard lining of the salt, from two and a half to three or four inches thick; this is detached and conveyed to the packing-house or store, and the residuary matter remaining in the body of the sublimers is removed to another part of the factory to be converted into sulphate of ammonia. The business of the packing-house is to separate from the cake the brown coating arising from contact with the iron, and the causes before alluded to, by means of axes, after which it is broken up into convenient pieces, and packed in casks and barrels for market. Messrs. KURTZ, CROPPER, and Co., prepare during the winter months about fifteen tons weekly of the impure chloride, part of which is sublimed, so that, on an average, about six to eight tons of the latter are weekly ready for the market: the remainder of the impure salt is used for the preparation of sesquicarbonate of ammonia, or other salts of this alkali. The greater part of the chloride of ammonium is employed by color-makers and calico-printers, and by metallurgists for galvanizing iron.

SULPHATE OF AMMONIA.—Sulphate of ammonia is obtained at the above-mentioned factory by the following process:—A large pipe, connected with the main liquor tank, mentioned in the foregoing pages, conveys a quantity of liquor to a large boiler in the part of the factory appropriated to the making of this article. The boiler is placed over a fire, the flue from which circulates round the bottom and sides; a large pipe issues from its upper surface top, and descends through an adjoining tun, containing sulphuric acid, to its bottom. By bringing the contents of the boiler to ebullition, the free ammonia is driven off through the pipe into the tun containing the acid; here it is absorbed by the sulphuric acid, giving rise to sulphate of ammonia. Distillation is continued till no more ammoniacal vapors are eliminated, and then the fire is checked, while the residual liquor is drawn off and mixed with cream of lime, to give it a strong alkaline reaction; the whole is then run into a second and larger boiler, like the preceding, on the principle of a still; under this a brisk fire is applied, and the ammoniacal vapors liberated by the action of the lime are transmitted through the sulphuric acid solution in the tun. After all the ammonia is obtained, the waste liquor is run off.

During the time the alkaline vapors are blown through the sulphuric acid liquor, much water is removed from the solution, by the heat from the steam and ammoniacal gas, so that, in further concentrating the liquor, less fuel is required. The evaporating pans are similar to those used for boiling down the chloride of ammonium solution; but much more care is requisite when fire is applied directly to the pans, than when the concentration is effected at a steam heat; for the organic matter which the liquor contains partially decomposes the sulphate into hyposulphite or sulphide, which reacts upon the iron pans, or by the excess of acid present is decomposed, giving off sulphurous acid or sulphide of hydrogen gas. The overseer should be careful in observing if any traces of an odor resembling that of rotten eggs, which characterizes sulphide of hydrogen, become sensible, this tells that the decomposition is taking place, and of course admonishes him that it should be prevented by immediately withdrawing the fire or slacking it. Crystallized sulphate of ammonia obtained in the first operation, is much purer than the chloride of ammonium already described, in consequence of the impurities of the crude liquor being removed by the distillation. After the crystallization, the crude liquor which is still acid is returned to the tun, to combine with further quantities of ammonia.

Besides the ordinary liquor, the impure chloride from the packing-house and the refuse of the sublimers are sometimes decomposed by lime, as in the preceding case, and the eliminated ammonia transmitted through the acid solution to form sulphate; but they are generally used to prepare the carbonate. The sublimation of the crystallized sulphate cannot well be effected; but chloride of ammonium may be prepared from it, by mixing it with a proportionate quantity of chloride of sodium, and then heating; the chloride is sublimed, and sulphate of soda remains in the bottom of the sublimer.

About six tons are manufactured weekly by Messrs. KURTZ, CROPPER, and Co., and from a million and a half to two million gallons of ammoniacal liquor are worked up annually. In subliming ammoniacal salts, considerable advantage results from the use of large vessels, as the labor of attending them is in a great degree lightened, and the fire which is requisite to heat an apparatus of three feet in diameter, would serve, with very little addition, to sublime the contents of one of nine feet; the time required also in working the charge of each sublimer, whether it be three, five, or nine feet diameter, is nearly the same, though the quantity of salt produced by the larger ones is very different. They have been used with satisfaction in the form described; but a further advantage would be gained by having the bottom—instead of being flat, as is the construction at present—rising in a slanting direction from the sides to the centre. In this way the heat would be sooner communicated to the whole of the material introduced, and the time required for sublimation would be shortened. Ammoniacal gas liquor yields from three-quarters to one pound and a quarter of salt per gallon of liquor, but this quantity is subject to much variation from many causes.

In the manufacture of chloride of ammonium, as already described, if the purification of the liquor be not effected before crystallizing the salt, some traces of protochloride of iron are generally present, and often it is found in large proportions. When the crystals are submitted to the heat in subliming, the chloride of iron is volatilized, and is blended with the ammoniacal salt in the colorless as well as in the dark or brown seams of the cake.

Wurtz, who examined this substance, states that neither the brown nor colorless portions of the sublimate give any indications of iron, with the usual reagents, until nitric acid has been added to convert the protosalt of iron into the sesquisalt, after which the blue precipitate, or coloration, with ferrocyanide of potassium, and the red with the sulphocyanide of potassium, become very distinct. It was not generally considered that the colorless chloride of ammonium contained iron, till the above-named chemist noticed it. It seems that, although the iron might be present originally in the lie as a sesquisalt, it is subsequently converted into a protosalt by the reducing power of chloride of ammonium. The reaction may be represented as follows:—

$$\underbrace{Fe_2\,Cl_3}_{\text{Sesquichloride of iron.}} + \underbrace{N\,H_4\,Cl}_{\text{Chloride of ammonium.}} = \underbrace{2\,(Fe\,Cl)}_{\text{Protochloride of iron.}} + \underbrace{2\,H\,Cl}_{\text{Hydrochloric acid.}} + \underbrace{N\,H_2}_{\text{Amidogen.}}$$

or—

$$\underbrace{3\,(Fe_2\,Cl_3)}_{\text{Sesquichloride of iron.}} + \underbrace{N\,H_4\,Cl}_{\text{Chloride of ammonium.}} = \underbrace{6\,(Fe\,Cl)}_{\text{Chloride of iron.}} + \underbrace{4\,(H\,Cl)}_{\text{Hydrochloric acid.}} + \underbrace{N}_{\text{Nitrogen.}}$$

In either case, the sesquichloride of iron is converted into the protochloride.

Repeated crystallizations might remove the iron compound, but this would cause a loss of time, fuel, and material. By following **Brewer**'s method, the smallest trace of this salt is separated without involving any additional expense. His process consists in passing a few bubbles of chlorine gas through a concentrated hot solution of the salt in the crude state, which converts the protochloride of iron into a sesquichloride; this in turn is decomposed by free ammonia, with the precipitation of hydrated sesquioxide of iron, and the formation of chloride of ammonium. The liquor is kept hot for some time, till the whole of the flocculent brownish matter settles to the bottom, after which it is rapidly filtered and set aside to crystallize. By this means a perfectly pure salt, free from the least trace of iron, is obtained. Great care should be taken to keep the solution hot during the time the chlorine is being transmitted through it, and also not to prolong the action, in order to prevent the formation of the well-known dangerously explosive mixture—chlorhydride of nitrogen—

$$N\,Cl_3,\ N \left\{ \begin{matrix} H \\ Cl_2 \end{matrix} \right.$$

The action of the chlorine in the first instance is represented by the equation:—

$$\underbrace{2\,(Fe\,Cl)}_{\text{Protosalt.}} + Cl = \underbrace{Fe_2\,Cl_3}_{\text{Sesquisalt.}}$$

and that of the ammonia, in precipitating the sesquioxide of iron from the latter, is thus:—

$$\underbrace{Fe_2\,Cl_3}_{\text{Sesquichloride of iron.}} + \underbrace{3\,N\,H_4\,O}_{\text{Ammonia.}} + \underbrace{3\,H\,O}_{\text{Water.}} = \underbrace{(Fe_2\,O_3,\,3\,H\,O)}_{\text{Sesquioxide of iron.}} + \underbrace{3\,(N\,H_4\,Cl)}_{\text{Chloride of ammonium.}}$$

The specification of Mr. **Croll**'s patent gives the following instructions for the preparation of ammoniacal salts:—A vessel, similar to those used for purifying coal gas by means of moistened quicklime, is filled with a solution of chloride of manganesium, made by dissolving one hundredweight of that salt in forty gallons of water, and the gaseous ammonia, generated in the usual way, is passed through it by the pressure from the retort. The manganic solution absorbs the ammonia, which precipitates a corresponding proportion of oxide of manganesium, and, as soon as fully saturated, it is drawn off, and a fresh charge introduced.

When sulphuric acid is combined with the alkali, a vessel, similar to that for washing the gas, is used, the sulphuric acid being of specific gravity 1·845, and in the proportion of two pounds and a half of acid to a hundred gallons of water. The gas is passed into it till the liquid marks a specific gravity of 1·170, when it is drawn off and a second charge supplied.

In preparing chloride of ammonium, the hydrochloric acid is taken at a density of 1·165 before diluting it, and then charged with the vapor till the gravity is 1·176; the proportion is the same as with sulphuric acid. In the preceding case of the manganese salt being used, the ammoniacal compounds are purified by filtering off the solution from the precipitated oxide, evaporating the filtrate, and subliming the residue. Sulphate of manganese, or protochloride of iron, may be substituted for the chloride of manganesium. That portion of metallic oxide which remains, is again converted into a fit state to absorb fresh quantities of the alkaline vapor, by the following simple method:—To every three parts of this residue, four of common salt are added, and the mixture heated in a furnace to low redness, which is scarcely perceptible in the dark, for about two hours or longer. Forty gallons of water are then added to every hundred and forty pounds of this mixture, and the liquid thus produced absorbs ammonia very rapidly. The precipitate which falls, consequent on the retention of the ammonia, only requires to be dissolved in the acid, which is intended to form a combination with the alkali, to render it suitable to serve the intended purpose a second and a third time.

Messrs. **Phillips**, **Watson**, **Jonson**, and others, have secured patents at various times for the production of ammonia and ammoniacal salts, but these scarcely differ from the old method of decomposing the substances with an alkali, and distilling off the volatile compound. **Hill** proposes to convert the ammonia eliminated in the distillation of coals into chloride, by mixing chloride of manganesium with the coals in the retorts, or introducing the chloride into a retort appropriated for the purpose; the heat dispels the hydrochloric acid, and this, uniting with the alkaline vapor, forms chloride of ammonium, which is retained in the liquor in the condenser. After removing the tar in the usual way, the salt is obtained by evaporation and sublimation, as before described.

Spence recommends a series of cylindrical-covered boilers, or reservoirs, placed at such different elevations that the contents of the uppermost may be drawn off into the next, and so on in succession to the lowest, as an economical arrangement in preparing chloride of ammonium, or sulphate of ammonia, from gas liquor, *et cetera.* Each boiler has an exit pipe, which carries the vapor generated in it to that which is next above it, and the exit pipe of the highest boiler passes off to a tank, where the acid requisite to form the salt is supplied. A charging pipe connects the top boiler with the reservoir of gas liquor, which is already mixed with milk of lime, and by turning a stopcock attached to it the boiler may be replenished. Four boilers are deemed sufficient, but a larger number may be used. A pipe, conveying high-pressure steam, enters the lower boiler, by which the liquid is made to evolve its ammonia into the next boiler; and in the same manner the contents of this and the upper boilers are brought to the temperature of ebullition, the ammonia passing through each by the connecting pipes, till it is expelled from the highest, in a very concentrated state, to the acid tank. When moderately concentrated acid is used after the absorption of the ammonia in the series of boilers, the lie is so strong that it may be drawn off at once to crystallize. As the liquor in the lowest boiler becomes exhausted of its ammonia, the fire is slackened and the contents run off, and that of the next boiler admitted instead; the latter is supplied from the one above it, and so on to the highest, which is filled from the reservoir. When the boilers are replenished, the fire is stirred up, and the distillation proceeded with as before. The solution of chloride of ammonium, or sulphate of ammonia, is treated in the usual way for obtaining the dry salt.

Salts of ammonia are prepared from guano in the manner specified by **Turner**, under the patent which he obtained in 1844 for this purpose. The guano is subjected to destructive distillation in close iron cylinders, at a low red heat during the greater part of the operation; this temperature is increased towards the end. The eliminated gases are made to pass through three Woulfe's bottles, or vessels arranged on that principle, in order that the whole of the condensable products may be retained. Carbonate of ammonia, hydrocyanic acid, and carbide of hydrogen, are copiously disengaged; the first two, being rapidly absorbed, give a strong solution of cyanide of ammonium and of carbonate of ammonia, while the carbide of hydrogen passes into the atmosphere.

As soon as the charge of the retorts has been exhausted, the solution in the condensing apparatus is drawn off, and mixed with as much protochloride of iron as is necessary to precipitate the whole of the hydrocyanic acid in the form of prussian blue. In consequence of the free ammonia present, the blue precipitate does not appear on adding the iron salt, but on neutralizing this ammonia with hydrochloric acid, it then falls down of a fine blue color; this is filtered off and well washed, after which it is converted into ferrocyanide of potassium—*yellow prussiate*—by boiling with potassa, evaporating the solution, and crystallizing in the usual way. If an excess of iron is present in the liquid filtered from the iron precipitate, it is separated by adding carefully a fresh quantity of the ammoniacal solution, which precipitates it, and it is then removed, and the neutral solution of chloride of ammonium evaporated. Sulphate of ammonia is procured in a similar manner, by employing sulphuric instead of hydrochloric acid, and sulphate of iron instead of the chloride.

By the action of sulphuric or hydrochloric acid upon stale urine, corresponding salts of the alkali are obtained by simply evaporating the solution, and crystallizing.

Peat is a substance which is rich in ammonia, and therefore the fabrication of ammoniacal salts from this source is one of the principal features in the works of the British and Irish Peat Company.

Reece directs, in the patent which he secured in 1849, that the peat should be carbonized in a blast furnace, and the combustible gases and volatile substances, given off during the ignition, conducted to a suitable condensing apparatus appended, wherein the tar, ammoniacal carbonate, naphtha, and other condensable compounds are retained. The tar is subsequently separated and employed for the production of paraffine and oil; the ammoniacal liquid is neutralized with an acid, then distilled, to procure the naphtha, and the residual product evaporated in the usual way.

According to the scientific statements which have been drawn up at various times by Sir **Robert Kane** and others, peat yields from twenty-two to twenty-five pounds of ammoniacal salts per ton, so it appears the dividends accruing to the company are pretty satisfactory.

For the preparation of the chloride or sulphate, **Laming**'s patent, obtained in 1850, claims the application of certain salts and compounds which are to be used in the purifiers of the gas-works, and through which the gases given off from the retorts are transmitted, so as to retain the ammoniacal vapor; these substances are chloride of iron, decomposed by hydrate of lime into oxide, with the formation of chloride of calcium; also the use of sulphate of iron, which he converts, by means of chloride of sodium, into chloride of iron and sulphate of soda; and the chloride thus prepared is then decomposed, as in the preceding instance, into oxide of iron and chloride of calcium. Further, the patentee claims the use of a mixture of sulphate of lime and sulphate of iron, or of the precipitated hydrated oxide of iron with carbonate of lime, magnesia, carbonate of magnesia, or magnesian limestone; of chloride of magnesium, or sulphate of magnesia and water; of phosphate of lime dissolved in hydrochloric acid; and of a mixture containing sulphate of magnesia, or chloride of magnesium or calcium, or one or more of these, in combination with oxide of copper, and mixed or not with lime or magnesia, or both or either, or both of the carbonates of those earths. In all of these cases, the salts or mixtures employed are mingled with sawdust, or some porous substance, before being placed in the purifying vessel. After they become saturated with the vapor of ammonia, the chloride or sulphate formed is removed by simply washing the mass with water. In his patent for 1852, he claims the use of sulphurous acid as a means of preparing sulphate of ammonia, and proceeds as follows:—The ammonia is liberated in the free state or as carbonate, by any simple means, and received in water; and by a stream of sulphurous acid gas, which he transmits through this ammoniacal liquid, forms sulphite of ammonia; finally, he oxidizes this salt into sulphate by agitation and exposure to the air.

Another patent was granted to Michiel in 1850, for his improved method of preparing sulphate of ammonia by means of sulphate of lead, containing an excess of oxide.

On submitting such compounds to the ammoniacal solutions, decomposition of the lead salt takes place, being converted partly into sulphide, and partly into a carbonate, which will be found suitable for many manufacturing purposes, while a sulphate of ammonia results. He prepares the oxysulphate in the following manner:—Native sulphide of lead is ground into small fragments; the reduced mass is then spread upon the higher of two shelves, constructed in a reverberatory furnace, where it is heated for about two hours. It is then drawn off to the under bed or shelf, where it is more strongly heated, and kept occasionally stirred to prevent fusion or caking of the mass, and also to have every part equally heated. The second heating effects the transformation of a portion of the sulphide into sulphate, while another part is oxidized and sulphur eliminated. The layer of galena is about two to two and a half inches in depth.

In December of the year 1850, Mr. Wilson secured another patent for preparing sulphate of ammonia from the waste products of coke ovens, *et cetera.* His method consists in transmitting the vapors through a circular tower, filled with coke pebbles, or other disintegrated bodies. A cistern at the base of the tower is filled with sulphuric acid, so diluted that, when completely saturated with ammoniacal vapor, the heat of the apparatus will not concentrate it so much as to deposit crystals of the salt. Another cistern, similar to the preceding, is placed on the top of the tower, the bottom of which is perforated. All the vapors from the ovens are forced through the lower cistern and up the tower, and, by an arrangement which continually raises the dilute acid liquor of the lower tank to the upper, so that it falls again through the perforations, any of the alkali that may escape combination from the cistern is taken up by the trickling solution in the body of the cylinder.

By filtration, evaporation, and crystallization, the sulphate of ammonia is obtained from the solution after the acid employed has been neutralized.

Dr. Richardson prepares the sulphate of ammonia by forming a double sulphate of magnesia and ammonia, and afterwards submitting this product to sublimation.

SESQUICARBONATE OF AMMONIA.—This compound of ammonia is prepared, on the large scale, by heating chloride of ammonium, or sulphate of ammonia, and chalk, in close vessels; double decomposition of the two compounds follows, which causes the formation of sesquicarbonate of ammonia, and a salt of lime analogous to the ammoniacal one taken. Three equivalents of the ammoniacal salt react upon three equivalents of chalk or carbonate of lime, and the result is one equivalent of sesquicarbonate of ammonia, one of free ammonia, and three equivalents of a lime salt, thus:—

$$\underbrace{3\,(NH_4Cl)}_{\text{Chloride of ammonium.}} + \underbrace{3\,(CaO,\,CO_2)}_{\text{Carbonate of lime.}} = \underbrace{(2\,NH_4O,\,3\,CO_2)}_{\text{Sesquicarbonate of ammonia.}} + \underbrace{NH_4O}_{\text{Ammonia.}}$$
$$+ \underbrace{3\,CaCl,}_{\text{Chloride of calcium.}}$$

or—

$$\underbrace{3\,(NH_4O,\,SO_3)}_{\text{Sulphate of ammonia.}} + \underbrace{3\,(CaO,\,CO_2)}_{\text{Carbonate of lime.}} = \underbrace{(2\,NH_4O,\,3\,CO_2)}_{\text{Sesquicarbonate of ammonia}} +$$
$$\underbrace{NH_4O}_{\text{Ammonia.}} + \underbrace{3\,(CaO,\,SO_3)}_{\text{Sulphate of lime.}}$$

The above decomposition may appear at a glance to be at variance with the general composition of bodies resulting from the mutual action of neutral salts, such as those taken in the preceding instance; for, conformably with the general behavior of the double decomposition of neutral compounds, it would be supposed that the change in the preceding would be—

$$\underbrace{3\,NH_4Cl}_{\text{Chloride of ammonium.}} + \underbrace{3\,(CaO,\,CO_2)}_{\text{Carbonate of lime.}} + \underbrace{3\,HO}_{\text{Water.}} = \underbrace{3\,(NH_4O,\,CO_2,\,HO)}_{\text{Neutral carbonate of ammonia.}}$$
$$+ \underbrace{3\,CaCl}_{\text{Chloride of calcium.}}$$

producing a carbonate of the oxide of ammonium and chloride of calcium, both of which are neutral bodies. According to the experiments of Rosé, it appears that the neutral carbonate of ammonia does not exist, *per se;* hence, even should it be produced at the first application, decomposition would immediately take place, and cause the evolution of gaseous ammonia and water, corresponding to NH_4O, or NH_3, HO.

Leaden chambers are used as condensers to retain the volatilized salt from the heated retorts; they generally have the top or bottom partly movable, or have a door in their sides, to allow of the removal of the salt. The crude sesquicarbonate obtained in the first sublimation, is purified by expelling it by heat from iron pots, surmounted by leaden caps. The waste heat of the flue from the furnace which heats the retorts, serves for this part of the work. In the second operation, water is added to render the salt translucent.

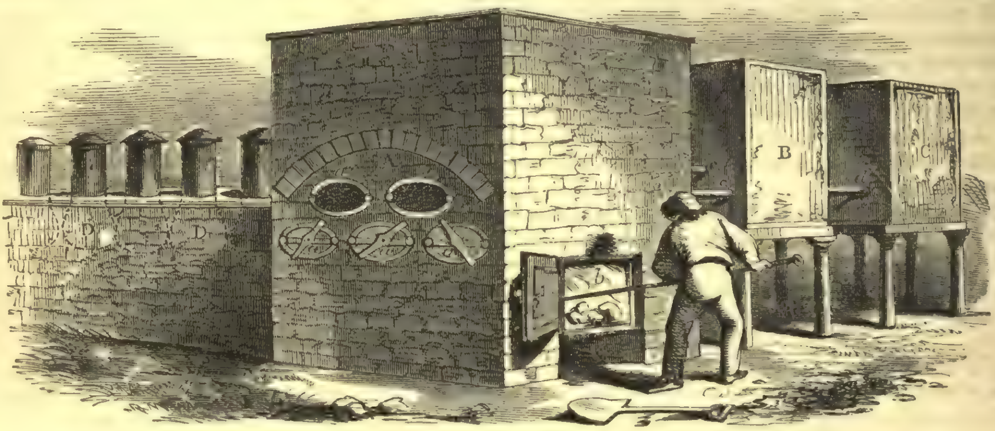
The annexed woodcut—Fig. 116—represents such an arrangement as is here mentioned. In this figure the retorts are cylindrical, and laid horizontally in the furnace, similar to those used in the carbonization of wood for the production of wood vinegar, having the exit pipe for the passage of the sublimed salt at the back; or they may be like those already described in the distillation of bones.

A is the exterior of the furnace containing the five retorts, *a a a a a*, laid horizontally, and closed at the front by iron doors made secure by bolts and screws.

Heat is communicated by the fire, *b*, at the end of the furnace. The pipes, *c c*, carry off the vapors of carbonate of ammonia into the chamber, B, and whatever remains uncondensed in this is discharged into a second one, C, by the connecting pipe, *d*. Both chambers are supported upon pillars or scaffolding, to bring them on a line with the retorts; D D, are the purifying pots, made of cast-iron, and surmounted with leaden heads, into which the carbonate is volatilized from any fixed impurities by the heat of the flue from the fire, *b*.

One part of sulphate of ammonia, or chloride of ammonium, mixed with one and a half or two parts of carbonate of lime, is introduced into the retorts, and a moderate heat applied at first, which is gradually increased towards the end of the operation. The vapors which are eliminated through the pipes, *c c*, in the figure, are condensed in the chambers, B and C. After the charge in the retorts becomes exhausted, the salt condensed in the chambers is removed to the purifying vessels, D D, where it is sublimed at a low degree of heat; sometimes 150° Fahr , communicated by a water-bath, is found to answer the purpose.

Fig. 116.



LAMING recommends, for the preparation of sesquicarbonate of ammonia, the conveyance of the constituent gases into a series of leaden chambers, on a large scale, the temperature of which should be kept as low as practicable, in order to induce as much as possible the combination of those gases. It is unnecessary to have them in atomic volumes; in fact, it is desirable that the carbonic acid should be in excess.

A stratum of water, or of a solution of ammonia, is supplied in one or other of the chambers, and in this case the resulting product is said to contain more carbonic acid than when the gases unite as they issue from the vessels where they are generated.

The solution is evaporated, and the salt purified by sublimation.

The same chemist prepares carbonate of ammonia from sulphide of ammonium found in gas liquor, by a novel process. Oxide of copper and charcoal are used in the proportion of twelve parts of the former to one of the latter; and this mixture is introduced into any suitable retort—cast-iron—wherein it is heated to redness; the pipe, joining the beak, passes through cold water previous to its entrance into the ammoniacal solution of the sulphide or the gas liquor. The action of the heat upon the oxide of copper and charcoal gives rise to carbonic acid, which, entering into the solution, displaces the sulphur in combination with the ammonium, and causes it to be dispersed as sulphide of hydrogen, while the carbonic acid takes its place, and a solution of carbonate of the alkali is formed.

When the carbonic acid ceases to be eliminated, the whole of the oxide is reduced to finely-divided metallic copper, and very little, if any, charcoal remains. The retort is cooled, and the contents drawn out, while another retort, similarly employed, maintains the stream of carbonic acid through the solution. During the cooling of the contents of the first retort, the finely-divided copper, by uniting with oxygen from the atmosphere, is reconverted into protoxide, which may be used over again with a fresh portion of charcoal; and so on, till the elimination of sulphide of hydrogen ceases, at which period the liquor is known to be saturated with the carbonic acid gas.

CRANE and JULIEN direct, for the preparation of carbonate of ammonia, cyanide of ammonium, or the free alkali, from any of the oxides of nitrogen, that a carbide of hydrogen gas should be brought into contact with such oxides in the presence of a body which may induce combination by means of contact. For this purpose they give preference to platinum-sponge; or asbestos coated with platinum foil answers the purpose. The platinum is placed in the calibre of a large tube, heated to about 600° Fahr., to reduce the temperature of the gases, and at the same time prevent the deposition of the carbonate of ammonia formed on the tube, and cause it to be forced onwards to a condensing medium. Any gases uncondensed in the carbonate of ammonia chamber, are made to traverse a solution of ammonia, or of iron, for the purpose of retaining the hydrocyanic acid collaterally formed.

Sesquicarbonate of ammonia is a white fibrous substance, found sometimes in the market in translucent cakes, of about two inches in thickness. It is soluble in four parts of water at 55° Fahr., in 3·3 parts at 62°, in 2·7 at 90°, in 2·4 at 105°, and in two parts at 120°.

On exposing this solution to the air, decomposition takes place, ammonia and carbonic acid are evolved, and a bicarbonate remains.

$$\underbrace{2\,(2\,NH_4O,\ 3\,CO_2)}_{\text{Sesquicarbonate.}} = \underbrace{2\,(NH_4O,\ CO_2)}_{\text{Neutral salt.}} + \underbrace{2\,(NH_4O,\ 2\,CO_2)}_{\text{Bicarbonate.}}$$

As already stated, the neutral carbonate does not bear exposure to the air without decomposing into ammonia and carbonic acid; hence the ammoniacal odor emitted from the sesquicarbonate of ammonia. Bicarbonate of ammonia, remaining after the exposure of the sesquicarbonate, is not so pungent as the salt which produces it. Medically, it is known as mild carbonate of ammonia. It yields a precipitate with bichloride of platinum in the presence of hydrochloric acid; with copper salts, it gives the characteristic blue color produced by ammonia; with the salts of the alkaline earths, it does not yield an immediate precipitate; on boiling the mixture, however, the insoluble earthy carbonate falls down.

The composition of the sesquicarbonate of ammonia, according to the analysis of Phillips and Rosé, is annexed:—

		Centesimally represented.			
	At. weight.	Theory.	Phillips.	Rose. I.	Rose. II.
3 Eqs. of carbonic acid,	66	55·93	54·2	50·55	53·4
2 Eqs. of ammonia,	34	28·81	29·3	28·66	30·7
2 Eqs. of water,	18	15·26	16·5	20·79	15·9
	118	100·00	100·0	100·00	100·0

Rosé states that the composition of the sesquicarbonate varies with the mode of preparing it. When obtained by the sublimation of the salt from chloride of ammonium—or any other compound of ammonia—and carbonate of lime, the product is a sesquisalt; but on subsequent sublimation, for the purpose of purifying, he says that it is only four-fifths sesquicarbonate, as his analysis indicates:—

		Centesimally represented.	
	Atomic weight.	Theory.	Found.
4 Eqs. of ammonia,	68	31·78	31
5 Eqs. of carbonic acid,	110	51·40	51
4 Eqs. of water,	36	16·82	18
	214	100·00	100

Scanlan is of opinion that the compound regarded as the sesquicarbonate of ammonia, is only a mixture of anhydrous carbonate and bicarbonate of ammonia; because, on washing sesquicarbonate with cold water, the bicarbonate of ammonia remains under the same physical form as the salt submitted to edulcoration, while the neutral carbonate is abstracted; further, he employs the formula ($NH_4O,\ CO_2 + NH_4O,\ 2\,CO_2$) to represent the sesquicarbonate, on account of the preceding behavior. The opinion of Pereira is opposed to these, for he assumes it to be a true chemical compound, both from its uniformity of composition, when prepared in the same way, and its crystalline structure; besides, he thinks the above representation of Scanlan to be less probable, because the anhydrous neutral carbonate is dissipated upon exposure of the salt to the air, and the bicarbonate always contains water. The Editor considers the view of Rosé the correct one. Sesquicarbonate of ammonia possesses a pungent odor, a hot and saline taste, and a powerful alkaline reaction; it is used in medicine as a stimulant and antacid, and is a useful source of other ammoniacal salts. Bicarbonate of ammonia crystallizes from the hot concentrated solutions of the sesquicarbonate, or it may be precipitated by alcohol; by the action of heat upon the sesquicarbonate, decomposition into various compounds, with more or less carbonic acid, ensues; the sesquicarbonate of commerce is a mixture of several of these.

The impurities of the sesquicarbonate are organic matter and small portions of the salt submitted to decomposition with chalk, which pass over to the chambers unchanged; sometimes it may contain hyposulphite of ammonia, arising from the decomposition of the sulphate of ammonia, when this salt has been used, and also traces of lead, derived from the leaden chambers.

Organic matter is detected simply by dissolving the commercial article in water, when a solution of a brownish or even blackish color is produced, while the pure salt affords a colorless liquid. Sulphates or chlorides are detected by dissolving the substance in water, adding a few drops of nitric acid, and dividing the solution into two portions; to one part chloride of barium is to be added, and to the other a few drops of nitrate of silver solution; a white precipitate in these menstrua shows the presence of sulphuric acid in the former, and of hydrochloric acid in the latter.

Hyposulphites are detected by dissolving a portion of the salt in acetic acid, and adding nitrate of silver; a precipitate is obtained, which is white at first, but soon turns black, in consequence of the oxide of silver being reduced by the deoxidizing effects of the hyposulphurous acid. Lead is detected by transmitting a stream of sulphide of hydrogen gas through a solution of the salt, which occasions a black precipitate, or coloration, if lead be present.

Acetate of Ammonia has been already described under Acetic Acid, see page 38.

In agriculture the salts of ammonia are most valuable, increasing in a remarkable manner the fertility of the land, provided the other constituents peculiar to the crop be present; hence they are to be found in all good manures, the value of which they greatly enhance. Ammonia constitutes one-fifth of the weight of genuine Peruvian guano; stable manure also yields it in large quantities, and it is one of the valuable ingredients of bone manure. Salts of ammonia are extensively used in calico-printing, in the preparation of leather, and in pewtering; in the latter, as well as in tinning sheet-iron and iron vessels, the chloride is preferred; and from its volatility, by which it excludes the air, and thus prevents the oxidation of the tin, it is productive of the greatest benefit in this art.

Estimation of Ammonia.—To the manufacturer who employs ammoniacal salts, it is very necessary that he should be able to ascertain their purity, so as to know their real value, and what amount of work he can perform with their aid; but it concerns the agriculturist particularly, to ascertain the quantity of ammonia which may be contained in the different kinds of manure he lays upon his land, with the hope of reaping thereby a rich harvest. It is still more especially the province of the amateur and professional chemist to know how to determine the per centage of this alkali, whether in soils, manures, or other compounds capable of affording it. To meet these requirements for the reader who may not be already conversant with such processes, the Editor subjoins the following instructions for his guidance.

Ammonia is determined, for the most part, either as chloride of ammonium, or as the double chloride of ammonium and platinum. The ammonia, in complex organic bodies, is sometimes ascertained indirectly from the volume of nitrogen which they afford, when such substances are treated as will be further described.

As Chloride.—In pure solutions of ammonia, carbonate of ammonia, or any other of its combinations with a feeble volatile acid, the alkali is invariably determined by saturating with hydrochloric acid, and evaporating the solution to dryness in a water-bath, till the whole of the free acid and moisture are removed; the dry residue, accurately weighed, gives the amount in the form of chloride of ammonium. Should the solution contain only chloride of ammonium, evaporation of the water and weighing of the dry residue will give at once the amount of that salt, from which the ammonia contained therein is calculated. If the substance be solid or liquid, in either case a certain portion is weighed, say thirty grains of the solid, and one thousand grains of the liquid; the former in a crucible or covered watch-glass, and the latter in a perfectly clean and dry beaker-glass, which should be rather small, and tared accurately before introducing the liquid. After the solid has been dissolved in water, the succeeding treatment is the same as with the solution; hydrochloric acid is added in very slight excess, and then it is to be evaporated carefully, so as not to cause spirting, neither should the vessel be exposed to dust or other accidental impurities. The evaporation is best conducted in a platinum dish, and when no further loss is sustained by heating in the water-bath, the dish and dry residue are weighed; the difference between this weight and that of the dish is the weight of the chloride of ammonium. If a platinum vessel be not at hand, the evaporation may be continued to dryness in the beaker-glass wherein the solution was originally taken, provided it be small, and the beaker and its contents weighed, as in the foregoing instance; but if this should not happen, when the greater part of the water has been driven off, the concentrated liquor is to be carefully transferred to a platinum crucible, or small thin porcelain dish, and also the washings are to be gradually added, the solution evaporated to dryness, and the perfectly dry mass weighed. When the weight of the vessel is deducted from the combined weight, the difference is, as before, the chloride of ammonium. Very accurate results are in this way arrived at, if ordinary care has been exercised, as the trace of chloride which escapes during the evaporation is almost imperceptible. With a similar degree of accuracy, the ammonia may be determined by substituting sulphuric acid for the hydrochloric, and proceeding as above; the ammonia is calculated from the weight of the sulphate. In 53·5 parts of chloride of ammonium, there are seventeen of gaseous ammonia, or twenty-six of the oxide of ammonium, so that by simple proportion the per centage of ammonia is found, thus:—If the above weight yielded twenty-five grains of the chloride, the calculation will be,—as 30 : 25 :: 100 : 83·33; and as 53·5 of the chloride contains 17 of gaseous ammonia, equal to 26 of the oxide, the next statement will be,—as

$$53{\cdot}5 : \left\{\begin{array}{c}17\\ \text{or}\\ 26\end{array}\right\} :: 83{\cdot}33 : \left\{\begin{array}{l}26{\cdot}47 \text{ per cent. of the gaseous body, or}\\ 40{\cdot}42 \text{ `` `` of the oxide.}\end{array}\right.$$

In 66 parts of dry sulphate of ammonia there are likewise contained 17 of dry gaseous ammonia, or 26 of the alkali; the amount of ammonia in the sample, when sulphuric acid is used, is determined similarly to the example given.

As a double salt of Ammonium and Platinum.—In this form, all those salts of ammonia which are soluble in alcohol may be determined by converting them into a chloride by the addition of an excess of hydrochloric acid, and evaporating to dryness; then, on dissolving the dry mass in a small quantity of water, and precipitating by a solution of bichloride of platinum in excess, a yellow crystalline deposit forms, which is the compound salt. The menstruum is carefully evaporated to dryness at 212° Fahr., the dry mass treated with a little alcohol, and then thrown upon a filter, where it is washed with alcohol till the filtrate ceases to have a yellow color, which the first washings possess, owing to an excess of bichloride of platinum. Should the filtrate not be colored, it shows that enough of the precipitant has not been used, and in such a case the operation is not satisfactory, and should be recommenced, taking care to have the bichloride in excess, which is known by carefully observing if the supernatant liquid, after the greater part of the crystals has fallen to the bottom, is of a yellow color; the salt is to be thrown upon a filter, and washed with alcohol as above directed. The filter should be carefully deprived of dust, dried at 212°, till the weight remains constant, before introducing the yellow crystalline compound; and after the substance has been thoroughly dried and weighed, the difference between the latter weighing of the paper and salt, and that of the paper alone, is the ammonia-platinum salt. Its constitution is the following:—

	Atomic weight.	Centesimally represented.
1 Eq. of ammonium,............	18	...... 8·06
1 Eq. of platinum,............	98·6	...... 43·03
3 Eq. of chlorine,............	106·5	...... 48·91
	223·1	100·00

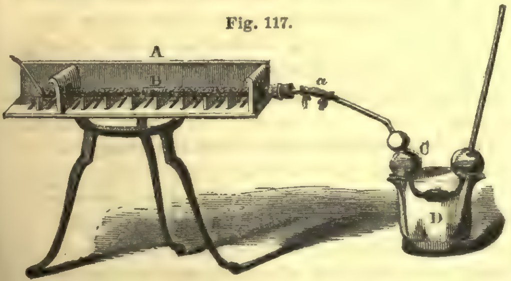
Formula: $N H_4 Cl, Pt Cl_2$.

Hence every two hundred and twenty-three parts of the precipitate contain seventeen of dry ammonia, or twenty-six of the oxide of the metal ammonium; or, centesimally, about 7·62 of the gaseous body, or 11·65 of the oxide, so that, by the assistance of these data, it is easy to arrive at the proper quantity contained in the sample under examination.

As a check upon the determination, the platinum compound may be introduced into a counterpoised porcelain crucible, and heated gently to redness, by which all the other components of the precipitate, except the platinum, are expelled; this metal remains in the form of a black spongy powder, which is to be weighed, and from its quantity, the ammonia contained in the sample is calculated by the following proportion:—As $98{\cdot}6 : \left\{\begin{matrix}17\\ \text{or}\\ 26\end{matrix}\right\} :: x$—the weight of the platinum found—: y—the corresponding ammonia; and then, as the weight of the compound taken : $y :: 100 : \frac{z}{y}$, the per centage of the alkali. During the ignition of the ammonio-chloride of platinum, the heat must be applied very gently at first, and the crucible kept covered, lest the too rapid evolution of chloride of ammonium should carry off some of the platinum, and give rise to an error. Towards the end of the operation the heat may be increased, and when no more vapors are observed, the crucible is allowed to cool, and then weighed.

When the ammoniacal compounds are insoluble in alcohol, they are analyzed by a more difficult way than either of the methods already described. The salt is ground with soda lime—a compound prepared by slaking pure caustic lime with a solution of hydrate of soda, of such strength that one part of the caustic alkali will be equal to two of the lime, after which it is heated in a Hessian crucible to dull redness, and then pulverized and retained for use in stoppered bottles—and the mixture heated in a combustion tube, in the same way as an organic analysis is conducted. A nitrogen apparatus—that recommended by WILL and VARRENTRAPP—is connected to the end of the tube by the aid of a perforated cork, which fits the latter perfectly tight; the bulbs of the apparatus are filled with hydrochloric acid of 1·20 specific gravity, for the purpose of retaining the ammonia which is disengaged from the heated material in the tube. Fig. 117 shows the arrangement as here indicated.

Fig. 117.



A is the combustion furnace, made of sheet-iron, and resting upon a tripod, or it may be supported upon a table or cast-iron plate; B, the combustion tube, about sixteen inches in length, and made of hard German glass, which bears the high temperature without fusing. The diameter of the tube should be about three-eighths of an inch, and one end should be drawn out to a point, sealed at the extremity, as seen in the engraving. The mouth of the tube is closed by a perforated cork, into which a small tube is introduced, and which is connected to the nitrogen apparatus, C, by means of a caoutchouc connecter, *a*. The nitrogen apparatus has four bulbs, which are filled with hydrochloric acid to the level represented; the apparatus rests upon a convenient support, D. By placing the long limb of the bulbed tube in a small glass filled with the acid, and applying suction to the other end, it is readily filled to the proper height. Great care must be taken that too much acid is not admitted, as then there would be a risk of spoiling the analysis by the liquid flowing back into the combustion tube.

Before proceeding to the determination, the substance should be thoroughly dried, either in the water-bath, or over sulphuric acid in the exhausted receiver of an air-pump; ten to twenty grains are then taken, and mixed intimately with the soda lime in an agate or glass mortar, which should be placed upon a large sheet of glazed paper, to prevent the loss of any particles that may be accidentally dropped during the grinding and filling of the tube. As much of the soda lime is put into the tube as is sufficient to fill about three-quarters of an inch, and then the mixture of the substance under examination and the lime compound is introduced as speedily as possible. The mortar is rinsed with successive small quantities of the powdered soda lime, and these are added to fill up the empty part of the tube to within two inches of its mouth. A loose plug of asbestos is now inserted, and the cork with small tube tightly fitted to it; a space through which the products of the combustion may traverse the tube is made by holding the latter in the hand, and giving it a few gentle taps horizontally against the table; the contents aggregate more closely, and an empty space is formed in the upper part. The tube is now placed in the furnace with the pointed end upwards, as seen in the figure, and the nitrogen apparatus attached by means of the connecter. Care must be exercised that all the joinings are air-tight; this the operator may ascertain by holding a glowing piece of charcoal to the inner bulb, till a few bubbles of expanded air escape to the middle one; if, on removing the coal, the liquid assumes the original level the connections are air-tight. Red-hot pieces of charcoal are now applied to the posterior part of the tube for a short time, to expel the air contained in the apparatus; and after that, the pieces are placed at the front end, and gradually retire as the matter becomes decomposed, till the whole of the tube is at a low red heat. Particular pains should be taken to eliminate the ammonia gradually and steadily, and, above all, not to allow the heat to remain stationary at any part of the tube, till all the ammonia contained in that part is expelled; for on removing the coals a vacuum is formed, which causes the reflux of the hydrochloric acid from the nitrogen apparatus into the tube. Hence the coals should be applied to a fresh part, before the matter already decomposing is completely exhausted.

When no more ammonia is given off, the pointed end of the tube is broken by a forceps, and suction applied to the long arm of the nitrogen apparatus, in order to draw over the last traces of ammonia that might remain in the apparatus; after which it is detached, and the chloride of ammonium solution transferred to a beaker glass, or platinum dish, together with the water used to rinse the bulbs, and the whole evaporated to dryness.

The residue thus obtained is dissolved in as small a quantity as possible of distilled water, filtered from any residue which may happen to exist in it, and the filtrate and washings precipitated by bichloride of platinum; the solution is then evaporated, and treated with alcohol. The remainder of the operation is conducted in the same way as already described. The results, when the operation is carefully performed, are very accurate.

The preceding process may be shortened, by taking a known weight of the hydrochloric acid—the quantity of real acid in which may be ascertained both from the specific gravity, and from an acidimetrical examination—and after the ammonia from the mixture in the combustion tube has been absorbed, the contents of the nitrogen apparatus are transferred to a beaker glass, together with the washings, and the excess of acid neutralized with a standard solution of ammonia, of specific gravity ·992, containing one equivalent of ammonia in a thousand grains of the solution. According to the number of grains or measures from a burette, required to saturate the free acid, the quantity of ammonia in the sample is calculated. Thus, if 300 grains of acid of 1·20 density, which contain 40·70 per cent. of dry acid, were taken, and required, after the ammonia in twenty grains of the mixture was absorbed, 267¼ measures of the ammoniacal solution to neutralize it; and knowing that every hundred measures, or a thousand grains of the test liquor, contain an equivalent of the alkali, which is capable of neutralizing thirty-six and a half grains of real acid—one equivalent—the total weight of free acid taken up by the test liquor is ascertained by simple calculation, and this deducted from the real acid in the three hundred grains employed as above, the difference is what had been saturated by the ammonia in the sample; and as 36·5 of hydrochloric acid is equivalent to 17 of ammonia, the ammonia in the sample is calculated from these data; *videlicet,*

36·5 : 17 :: x—the acid taken up—: y—the ammonia in the sample;

and centesimally—

As 20—the number of grains of the mixture—: y :: 100 : y', the per centage.

A more delicate way by which the quantity of the excess of acid is found, is, according to PELIGOT, by dissolving caustic lime in a solution of sugar, and neutralizing the acid with the solution thus obtained. The liquid is preserved from contact with carbonic acid in well-stoppered bottles; should carbonic acid be absorbed, it causes a white precipitate of carbonate of lime, which may be removed by filtration, and the solution thus clarified serves the intended purpose.

The saccharate of lime thus formed has an alkaline reaction, and neutralizes acids like an alkaline carbonate. Its saturating power is tested by reducing pure concentrated sulphuric acid to a density of 1·25 by means of water, after which five hundred grains, or any convenient quantity, is taken, and the weight or measure of the saccharate of lime liquor necessary to neutralize it noted. By calculating from the specific gravity, the weight of dry acid present in the liquor taken for the experiment is found, which is equivalent to the volume of the test liquor acid, say one hundred divisions of the burette. These numbers will remain a constant factor as long as the saccharate of lime is made of a uniform strength, and, therefore, any amount of acid in a sample is proportionate to the number of divisions of the liquor required to saturate it, and may be calculated accordingly. To apply it to the foregoing experiment:—After the whole of the ammonia is absorbed, the content of the sulphuric acid dish is transferred to a tall testing glass, and the prepared liquor poured in from a burette, till the acid is exactly neutralized, which is known by a strip of litmus paper in the usual way, as well as from the bluish tint which the solution acquires. The number of measures of test solution used is read off; from these the quantity of dry acid remaining of the five hundred grains is found in the way already alluded to; and deducting this from the total weight of dry sulphuric acid, the difference will be the quantity taken up by the ammonia of the sample experimented upon, and which is found by calculation.

To give an example:—Let fifty grains of the sample be treated as directed in the foregoing, using three hundred grains, or any other convenient weight of the acid, of the normal density 1·137; and after the whole of the ammonia has been absorbed by the acid, the surplus of the latter requires, say sixty measures of the test liquor. Now, if it be previously ascertained what quantity of this test solution is required to neutralize one hundred grains of the acid of 1·137 density, equal to 27·72 of dry acid, which may be here taken as fifty, the free acid remaining of the three hundred grains above is easily found; for, as 50 : 27·72 :: 60 : 33·264; and this sum deducted from the dry acid, is the quantity of acid taken, *videlicet,* 83·16 = 27·72 × 3, the difference will be 50 in round numbers. It being known that forty parts of dry sulphuric acid combine with sixteen of gaseous ammonia, or twenty-six of the oxide, the corresponding weight of ammonia taken up by the fifty grains is found thus:—As

$$40 : \left\{\begin{matrix} 17 \\ \text{or} \\ 26 \end{matrix}\right\} :: 50 : \left\{\begin{matrix} 21{\cdot}0 \text{ of gaseous ammonia,} \\ \text{or} \\ 33{\cdot}3 \text{ of the oxide,} \end{matrix}\right.$$

and the per centage of ammonia in the sample is ascertained by the same simple proportion:—As 50 : x :: 100 : y.

Ten thousand tons were about the average manufacture of ammoniacal salts last year—1853—of which about three thousand eight hundred tons were chloride, four thousand five hundred tons sulphate, and about one thousand seven hundred tons were bicarbonate; the former sells at a cost of twenty-five to twenty-eight pounds the ton, the sulphate at seven pounds, and the bicarbonate at thirty to thirty-five pounds per ton, according to its quality.

ANTIMONY.—*Antimoine,* French; *antimon,* German; *stibium,* Latin.—Primarily, a metallic ore consisting of sulphur combined with a metal; the stibium of the Romans. It has been shown at page 48, that the ancients used to designate an antimonial preparation by the appellation *alkohol.* It was used for painting the eyebrows, and Eastern ladies still apply it for that purpose; it no doubt imparts a degree of freshness to the complexion, and adds in many instances to its beauty; it bore a Greek name, signifying large eyes, from the circumstance of its being employed for the embellishment of those organs. Modern science has discovered that the substance known to the ancients was a sulphide of antimony, which is, consequently, the first compound of the metal on record; the word is also used in modern times to denote the pure metal.

The principal ores of antimony are found in the mines of Bohemia and Hungary, in France, England, and in America. During the age of alchemy, various other antimonial compounds were discovered; and an account of the metal is found in the writings of BASIL VALENTINE in 1460.

Antimony is met with abundantly in nature—metallic, combined with other metals; namely, with a little silver and iron in native antimony; with silver in antimonial silver; with arsenic in arsenical antimony; with sulphur and sulphides of other metals—for example, *per se*, in grey antimony, which generally contains copper, arsenic, and iron; with iron in Berthierite; with nickel and arsenic in nickeliferous grey antimony; with lead and traces of iron, copper, bismuth, and zinc in Jamesonite; with lead, copper, and iron in Bournonite; with lead, and a trace of copper, in zinkenite; with lead in antimonial lead glance; with silver and copper in melan glance; with silver, copper, and iron in miargyrite; with silver in dark ruby silver, rhombohedral ruby blende; with silver and arsenic in light ruby silver; and with arsenic, silver, and iron in arsenical silver. It is found, more or less, in the following argentiferous minerals; namely, with silver, copper, iron, and zinc, in weissgiltigerz and graugiltigerz; with copper and silver in antimonial grey copper, tetrahedral copper glance; and in very minute quantity, with copper, iron, silver, and arsenic, in kupfer-blende. It occurs as an oxide in white antimony, which is sometimes contaminated with sesquioxide of iron, and with sulphide of antimony in the red antimonial ore; also as antimonious acid in antimonial ochre.

Antimonial copper—*Antimonkupferglanz*, German—is composed, according to SCHRÖTTER'S analysis, of—

	Centesimally.
Lead,	29·902
Copper,	17·312
Antimony,	16·644
Arsenic,	6·036
Iron,	1·404
Sulphur,	28·702
	100·000

Such results do not conveniently admit of being represented by a chemical formula. If the metals enumerated be calculated as sulphides, thus, $Pb\,S$, $Cu\,S$, $Fe\,S$, $Sb\,S_3$, and $As\ S_3$, the amount of sulphur taken up would be only 25·229, whereas the analysis yields 28·602.

The principal sources of the antimonial ores are the Continental mines, very little of the metal being found in this country. The ore submitted to reduction is the sulphide of antimony—grey antimony—of which from six hundred to a thousand tons are annually imported into England.

In the laboratory, the metal is prepared in a variety of ways: if eight parts of powdered sulphide of antimony be intimately mixed with six parts of tartar—tartrate of potassa—and three of nitre, and the mixture be thrown in small portions into a red-hot crucible, and kept at redness for some time, a metallic button collects at the bottom. The antimony thus obtained is, however, impregnated with small traces of iron, and resembles the better sort of the crude metal found in the market.

When the sulphide of antimony—mixed with some charcoal to prevent the caking of the mass—is heated in contact with air, the greater part of the sulphur is expelled and teroxide of antimony formed; this may now be reduced to metal, either by fusing with an adequate quantity of black flux, or with the addition of ordinary soap; a button of impure metal remains. The purest antimony is procured by reducing either the teroxide with powdered charcoal and alkali, or the potassio-tartrate at a proper degree of heat.

As met with in commerce, antimony is more or less impure, in consequence of some imperfections or mismanagement in the process of its reduction. The contaminations are generally lead, iron, arsenic, and sulphur; but these may be separated by grinding the crude metal in an iron mortar, and fusing the powdered mass with one-tenth of its weight of nitrate of potassa, which oxidizes all the foreign ingredients, as well as a part of the antimony, leaving the remainder in a pure state.

Antimony is very brittle, possesses a white silvery aspect, and a plated crystalline texture, so that, when broken up, the fracture exhibits beautiful facets. It happens, also, that when the metallic button of antimony is suffered to cool in the crucible, the surface presents a fine stellated appearance. In consequence of this crystalline property, the alchemists considered the phenomenon symbolical of that mysterious luminary which was to guide them in their occult path to the discovery of a universal medicine, or the philosopher's stone.

At 800° Fahr. the metal fuses, and at a white heat it slowly but distinctly volatilizes in closed vessels; in a current of hydrogen, however, it distils with tolerable facility. If exposed to a stream of oxygen, on ignited charcoal, it burns brilliantly, evolving a white light, and is at the same time converted into the teroxide, which is eliminated in the form of a thick whitish smoke. Should a globule of the metal, at a high temperature, be dropped from an eminence upon a board, or plate of iron, the mass subdivides into numerous smaller globules, which hop along the plane in a combustible state, marking the course they take by a white streak or line.

Antimony is not sensibly affected on exposure to the air at the ordinary temperature; its surface becomes slightly tarnished, but does not rust. If exposed to the air during fusion, rapid oxidation takes place.

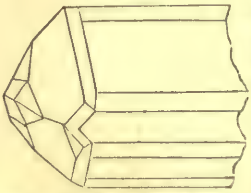
Hydrochloric acid dissolves antimony with the evolution of hydrogen, and the formation of the terchloride; concentrated sulphuric acid oxidizes it, sulphurous acid being at the same time evolved; but if the acid be diluted with water, it does not dissolve it. Nitric acid, even when very dilute, rapidly attacks antimony, and converts it into a white insoluble powder—teroxide of antimony, antimonious or antimonic acid, according to the strength of the acid and the time of digestion.

Aqua regia converts the metal into the terchloride. The specific gravity of antimony is 6·712, and the specific heat, according to **REGNAULT**, is 0·05077; its atomic or combining weight is 129, and its chemical symbol Sb, derived from the Latin, *stibium.*

For preparing the metal on a large scale, the sulphide is generally employed, as well for the abundant produce which it yields, as from the reduction being more easily effected than that of any other ore of the metal, with the exception of the native oxide; the latter, however, is never met with in sufficient quantity, and, consequently, is seldom used.

There are two varieties of the sulphide of antimony, the massive and the fibrous: the former presents a long columnar composition; and the latter is distinguished by its plumous, woolly, or felt-like appearance; it is of a light lead color, but sometimes dull externally, and often iridescent.

Fig. 118



The mineral is met with in crystals of the rhombic prism—Fig. 118—which are sometimes aggregated laterally. Before the blowpipe, on charcoal, sulphide of antimony fuses, and is absorbed, giving off at the same time sulphurous acid and white fumes of the teroxide of the metal.

The most celebrated localities productive of this mineral are, Felsobanya, Chemnitz, and Cremnitz, in Hungary, whence the grey antimony is procured; Dumfriesshire in Scotland, where the fibrous and laminated variety is found; and Cornwall, where the massive sort is raised. Other varieties of the sulphide are also to be found, as at Magurka, in Hungary; at Freyberg and Braunsdorf, in Saxony; and at Stolberg, in the Hartz. Various analyses of the sulphide have been made, which, of course, differ in their results, according to the greater or less amount of foreign matter present. The appended analyses of the pure mineral, by **THOMSON** and **BERGMANN**, show its composition:—

			Centesimally represented.	
	Atomic weight.	Theory.	Thomson.	Bergmann.
1 Eq. of antimony,	129	72·89	73·77	74·0
3 Eq. of sulphur,	48	27·11	26·23	26·0
	177	100·00	100·00	100·0

MANUFACTURE OF ANTIMONY ON THE LARGE SCALE.—Many of the operations in the preparation of antimony on the large scale are the same as those which will be mentioned hereafter, when describing the dry assay of the antimonial compounds. The method most commonly followed is, first to deprive the sulphide of antimony of its sulphur, and substitute oxygen by heat and free access of air, as in the annexed equation:—

$$\underbrace{\mathrm{Sb\,S_3}}_{\text{Tersulphide of antimony.}} + \underbrace{\mathrm{O_9}}_{\text{Oxygen.}} = \underbrace{\mathrm{Sb\,O_3}}_{\text{Teroxide of antimony.}} + \underbrace{\mathrm{3\,S\,O_2}}_{\text{Sulphurous acid.}}$$

This change is conducted in a reverberatory furnace, where the comparatively large amount of oxygen required to displace the sulphur, which is also oxidized, is derived from the superabundant current of air flowing over the heated mineral. During the roasting, the attendant should be mindful of the great volatility of the sulphide of antimony, and regulate the heat to prevent the loss of material which would attend the application of a too elevated temperature. The charge of sulphide should be well stirred with an iron slicer or spatula during the roasting, to insure every part coming in contact with the atmosphere. When properly roasted, the mass has a greyish-white appearance.

Having obtained the oxide in the manner described, it is intimately mixed with about a tenth of its weight of crude tartar, and reduced in large earthen crucibles, heated in a wind furnace, when the subjoined decomposition takes place:—

$$\underbrace{\mathrm{Sb\,O_3}}_{\text{Teroxide of antimony.}} + \underbrace{\mathrm{K\,O, C_8\,H_4\,O_{10}}}_{\text{Tartrate of potassa.}} = \underbrace{\mathrm{Sb}}_{\text{Antimony.}} + \underbrace{\mathrm{K\,O, C\,O_2}}_{\text{Carbonate of potassa.}} + \underbrace{\mathrm{7\,C\,O}}_{\text{Carbonic oxide.}} + \underbrace{\mathrm{4\,HO}}_{\text{Water.}}$$

The antimony thus obtained is tolerably pure, and is ready for market. Iron is the principal, and often the only impurity present.

At Linz, in Germany, a furnace, similar to that represented in the annexed cuts, was constructed for the reduction of antimony at one operation. Fig. 119 shows a vertical section; the bed is concave, and is constructed of sand and clay well consolidated; at its middle, a pipe, *a*, forms a canal for the fused metal to flow out as soon as produced, and which is closed by heavy ashes. *b* is the air channel in the bridge *d*, and *c* is a door through which the prepared ore is introduced and the residuary slag abstracted. The fire is shown at *f*; *e* is the grate, and *g* the chimney.

Fig. 119.

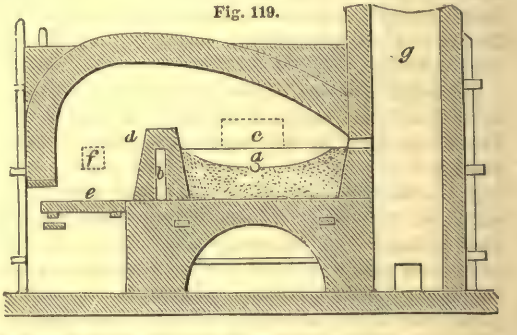


Fig. 120.

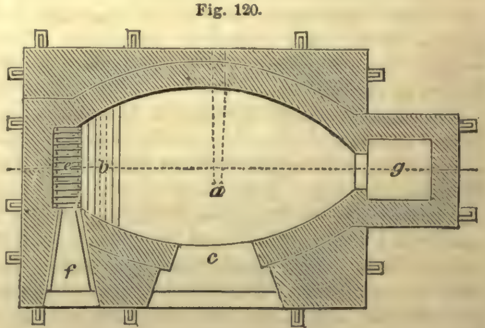


Fig. 120 is a plan of the preceding, wherein the same letters indicate the same parts as previously described.

Sulphide of antimony is dressed for reduction by mixing it with the proper quantity of iron, or iron scales, and alkaline carbonate. Two or three hundredweight of ore require from eight to ten hours' heat for reduction; but the metal obtained in this way is very impure, and is, therefore, remelted in portions of from twenty to thirty pounds in crucibles, covered over with ground charcoal, and heated in a reverberatory furnace.

The metal obtained by this process contains considerable quantities of iron, sulphur, and frequently arsenic, lead, and copper; and as these bodies deteriorate its quality, even for the arts, and as it cannot be employed in medicine while the smallest trace of arsenic is present, it becomes imperatively necessary to subject the crude article to purification. For this purpose it is fused with one-eighth part of sulphide of antimony, and an equal weight of carbonate of soda, in a hessian crucible, for one hour. On breaking the crucible, after cooling, the metal is carefully separated from the slag and submitted to a second fusion with one part and a half of the carbonate, and sometimes a third fusion may be required; but in this case it is to be performed with one part of the alkaline carbonate. Should there be lead, it remains in the antimony after the second fusion, although the other metals may be completely removed; and from its great fusibility, slight portions are retained even after the third operation.

If arsenic be absent, a part of the metallic antimony is oxidized and remains in the slag; but very little, if any, of the metal is thus acted upon whilst arsenic is present.

It has been found that a hundred parts of the crude metal and six parts of the sulphide yield ninety-four of pure antimony. It is necessary, when larger quantities of iron are present, to add proportionally more of the sulphide of antimony—as eight parts of the impure metal, two of the sulphide, and two of carbonate of soda; for, unless there be sufficient sulphur to combine with the whole of the iron, the arsenic cannot be oxidized.

Wöhler recommends deflagration of ten parts of the metal with twelve of saltpetre and ten of carbonate of soda; the arsenic is oxidized, and forms an arsenite of potassa, and also the antimony converted into antimoniate of potassa by this treatment. On boiling the fused mass with water, the arsenical compound is dissolved, leaving the antimoniate, which is collected, washed, dried, and reduced in the usual way with charcoal in an earthen pot.

The metal obtained by this means still contains copper and iron.

According to **Berzelius**, the impurities are removed by fusing two parts of the metal in fine powder with one part of teroxide of antimony; the iron, copper, and arsenic are oxidized, and remain in the slag; in this case the lead—should any be present—is still combined with the antimony. The Editor suggests that it is better to fuse a little more than four parts of antimony with one part of peroxide of manganese, and to subject the regulus so obtained to a second fusion with one-tenth of its weight of carbonate of soda.

As the sulphide of antimony is nearly always associated with seams of silicious and calcareous impurities, a preliminary operation is resorted to in order to separate them; this process is called *eliquation*.

Any difference that exists in the manner of eliquating crude sulphide of antimony is chiefly in the furnace employed. In Hungary, the ancient method of introducing the ore into large pots or crucibles is still practised. These pots are furnished with an aperture at their bottom, opening into a smaller one, which is embedded in the ground. A cover is appended to the upper pot, which may be luted down after the vessel is charged. These pots are placed in a circle with a furnace in the centre, the heat from which passes freely under the bottom and round the body of each pot.

Figs. 121 and 122 are drawings of this arrangement; the former is a section of the elevation, and the latter a plan, showing the position of the crucibles round the fire. *a a a* denote the pots wherein the crude ore is heated, and *c c c* the smaller pots which receive the liquid sulphide; *d* is the fire-grate. In the elevated section, the relative position of these crucibles is comprehensively shown, with their connecting tubes, *b b*; both crucibles and tubes are made of earthenware.

Fig. 121.

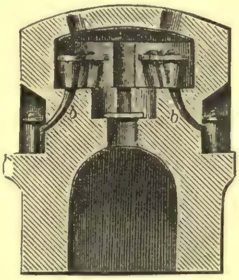


Fig. 122.

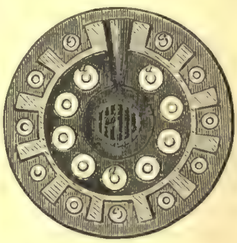
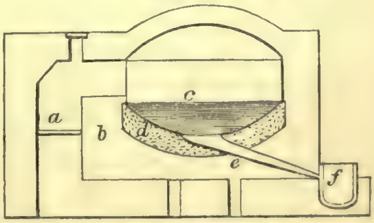


Fig. 123.



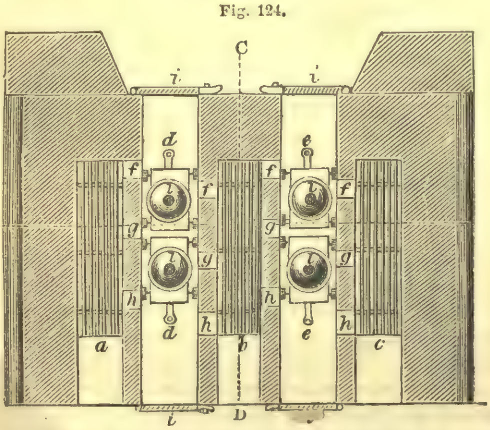
The furnace employed for the eliquation of the crude sulphide, at Vandée, in France, is represented in Fig. 123, where, instead of several pots being situated around the fire, the bed of the reverberatory, which is connected with a recipient for the purified material, supplies their place. In the figure, *a* represents the fire-place, *b* the bridge of the furnace, *c* the concave hearth, lying on the substrata, *d*; *e* is the pipe which issues from the bottom of the furnace hearth, and carries the liquid products along to the recipient, *f*. The furnace is heated by the flue passing around the body, and the charge is introduced through an opening in the dome, not shown in the woodcut. Such a construction of furnace is preferable to the preceding, both from the simplicity of its arrangement and the advantage of its being reverberatory. When moderately rich ores are subjected to purification, the charge, which is usually from eight to ten hundredweight, yields from four to five hundredweight of the purified substance, with a consumption of about twenty-five cubic feet of wood as fuel. Three such charges may be worked off in the long days of summer.

The best furnace for the separation of the sulphide of antimony from its matrix, is that in use at the extensive mines of Malbose, in the Ardèche Department in France, and is sketched in the subjoined engravings. Fig. 124 is a vertical view of the plan on a line with the flues which issue from the several fires, and which are denoted by the letters *f g h*, and the grates, whereon the ignited fuel is supported, by *a b c*. These grates are four feet and a half in length by about a foot in breadth, and are separated by two square galleries, *d* and *e*, running parallel through the furnace, and protected from the direct action of the fire by walls, having the alternate openings, *f g h*, serving as flues, to conduct the heat into the galleries, which are closed by the iron doors, *i i*, at each end.

Fig. 125, the elevated section of this plan, explains the nature of the arrangement.

In this drawing all the parts before referred to are indicated by the same letters. The galleries, *d d*, hold two large crucibles, *k k*, of cast-iron; and, in order that they may not adhere to the sulphide of antimony which flows into them, they are covered with clay luting. To each of these crucibles a set of wheels, running on parallel bars of iron, leading into the furnace, is affixed. In this way the crucibles are charged, fixed in the furnace, and withdrawn with facility. Both galleries are covered with flat tiles of firebrick, *l l*, on which the conical fire-clay cylinders, *m m*, rest. Sulphide of antimony for eliquation is introduced into these fire-proof cylinders, and the product, purified by fusion, is received in the lined crucible beneath the cover, *l l*, through the connection, or small opening, *n*, at the base of the cylinders. *q q* is the arch of the furnace through which the cylinders ascend, by openings somewhat larger than their outer diameters; these orifices are closed at the top by clay covers, *r r*. The arch at the top, *s*, is constructed cylindrically, forming a double cross arch.

Fig. 124.



After the flame from the fire has played round the cylinders containing the mineral, it departs through three openings and flues into the chimney, *t*—Fig. 126. Two of these openings are indicated by the letters *u* and *v*, in this figure, which is a section of the elevation following the line, C D, of Fig. 124; these flues are provided with valves. *w* is a chimney for carrying off antimonial vapors which may be expelled from the cylinders while drawing out the slag and exhausted ore. Another chimney, *x*, begins above *y y*—see Fig. 125—where the cylinders are charged; a partition, *z*, divides this chimney into two parts, so that the workman, while operating on one side, is not inconvenienced by the fumes of the other. *o o* are orifices several inches in height, by which the cylinders may be reached from the front and back part of the furnace by conical

Fig. 125.

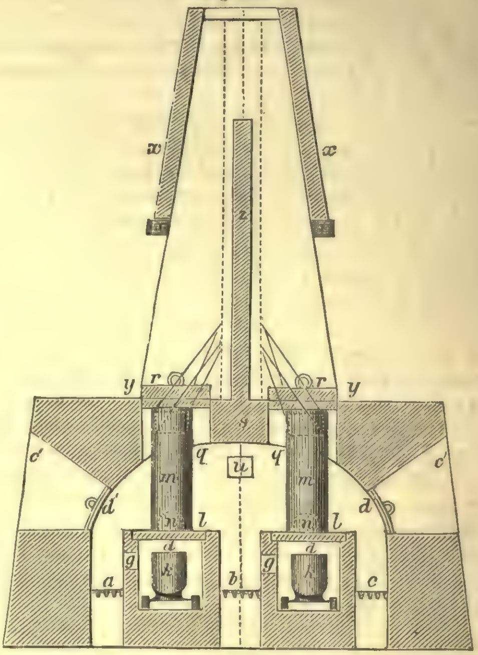
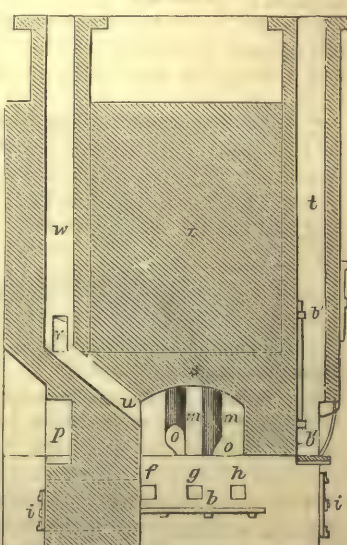


Fig. 126.



openings, such as *p*, in the walls; the openings, *o o*, are closed during the working with clay stoppers, *n n*, seen in the preceding figure, which are removed at the end of an operation. *a′* and *b′ b′* are iron and wooden beams and bands to brace the chimneys. *c′ c′* are conical arches on both sides of the furnace, closed with well-fitting plates, *d′ d′;* through these the interior of the furnace may be examined, and repairs made, when required.

Each cylinder is charged with four hundred and ninety pounds of ore, previously warmed on the arch, the coarsest and richest of which is placed at the bottom of the cylinders. As soon as the eliquation is completed, the impurities remaining are withdrawn through the openings, *o o*, and a fresh charge introduced. The sulphide of antimony produced should have a bluish color; if it possesses a reddish appearance, it is indicative of too great a heat. When the iron recipients are three quarters filled, they are drawn out and allowed to cool, and the lump of crude antimony—sulphide—removed. Fresh charges are put in every three hours, and about one hundred pounds of the sulphide obtained at each process, when the furnace is in successful operation. On an average, the cylinders last about twenty days.—*Booth.*

The product from the preceding operations is roasted in a reverberatory furnace to expel the whole of its sulphur, and produce instead the teroxide of the metal; the latter is subsequently reduced by mixing it with about twenty per cent. of charcoal, saturated with a strong solution of carbonate of soda. According to Berthier, seventy per cent. of good metal may be procured from the ordinary product of eliquation of the crude sulphide, as above, when mixed with sixty parts of iron scales from the hammer or rolling mill, forty-five to fifty of carbonate of lime, and ten to twelve of powdered charcoal, and the mixture heated to fusion in the ordinary way. Iron is often found in considerable quantities in the antimony procured from this mixture; and, therefore, unless subsequently purified, it cannot, in many instances, be advantageously employed.

Uses in the Arts.—Antimony is chiefly used as an ingredient in the construction of alloys, such as type-metal, Britannia-metal, plate-pewter, and various others. The typefounder uses two alloys of antimony, lead, and tin; the one composed of—

Tea lead,....	75	and the other	Tea lead,.....	70
Antimony,..	20		Antimony,....	25
Block tin,...	5		Block tin,.....	5
	100			100

Stereotype metal is formed of

Tea lead,........................	112 lb.
Antimony,........................	18 "
Block tin,........................	3 "
	133

The best Britannia-metal in one of the largest manufactories in Birmingham is composed as follows:—

	Centesimally.
Tin,..............................	90
Antimony,........................	10
	100

A higher proportion of antimony is sometimes used. From three to six per cent. of copper was formerly added; but this metal is now discarded, or is only used to give color, in the proportion of about one and a half per cent. for good metal. The best Britannia-metal is nearly all tin, with no addition but antimony, as above stated. Lead, which is given in some recipés, is carefully avoided. Bismuth is also rejected in good articles. Nearly every manufacturer, however, uses different proportions, according to the quality of his tin, a small quantity of which he previously tries with antimony, to find out the best result with that particular quality of tin upon which he is about to operate.

The specific gravity of the first three alloys above mentioned is greater than the calculated mean of the metals, on account of a contraction of volume taking place at the moment of cooling. With those alloys where tin is in excess, the result is opposite, for at the point of solidifying the mixture expands, and, consequently, the gravity is reduced.

Antimony is used as an ingredient in the preparation of concave mirrors for giving a finer texture to the mass, on which account it takes a better polish; and in the casting of bells, for the purpose of giving a clearer and stronger sound, as also to make them harder and whiter than they would otherwise be. From its easy fusibility, it is used to promote this property in other metals which may be employed for artistic or manufacturing purposes, especially in casting cannon balls.

The negative elements with which antimony forms the principal compounds are, oxygen, sulphur, and chlorine, which unite with it in various proportions, as seen in the annexed table:—

Name.	Symbol.	Atomic weight.
Teroxide of antimony,....	$Sb\ O_3$	153·0
Antimonious acid,........	$Sb\ O_4$	161·0
Antimonic acid,..........	$Sb\ O_5$	169·0
Tersulphide of antimony,..	$Sb\ S_3$	177 0
Quadrasulphide,..........	$Sb\ S_4$	193·0
Pentasulphide,...........	$Sb\ S_5$	209·0
Oxysulphide,.............	$Sb\ S_3$, $Sb\ O_3$	330·0
Terchloride of antimony,..	$Sb\ Cl_3$	235·5
Quadrachloride of antimony,	$Sb\ Cl_4$	271·0
Pentachloride of antimony,	$Sb\ Cl_5$	306·5

It also unites with bromine, iodine, and selenium.

Of the preceding compounds, the tersulphide, terchloride, and teroxide, are the only important bodies in a manufacturing point of view; and are, with the exception of the tersulphide which is employed to prepare the metal, almost exclusively used in medicine. These will now be described.

Tersulphide of Antimony.—*Crude antimony—antimony ore—sesquisulphide of antimony; schwefelspiessglanz—anderthalb—schwefelspiessglanz rohes antimon,* German; *stibium sulphuratum nigrum, lupus metallorum,* Latin.

Having already described the principal use of this antimonial compound, and the method followed for purifying it, nothing further remains but to add a few words on the manner in which the pure sulphide is procured for other purposes. That noticed in the foregoing, even after careful eliquation, contains variable quantities of sulphides of iron, lead, copper, and arsenic; hence the black streak which the eliquated compound makes, instead of a blackish red, which is formed by the pure substance. It may be prepared in the dry way, by fusing thirteen parts of pure antimony and five of flowers of sulphur—sublimed sulphur—in a crucible, the mixture being introduced by degrees and at short intervals. After the whole has been fused, the crucible is taken from the fire and inverted, to allow the melted sulphide to flow out. The whole of the metal may not be decomposed in this operation, but those portions which have escaped the action of the sulphur are easily removed.

In the humid state, sulphide of antimony may be manufactured in various ways: firstly, by conducting a stream of sulphide of hydrogen gas through a concentrated solution of tartar emetic—bitartrate of antimony and potassa—an orange red precipitate is formed, which is the sulphide in question; secondly, when *kermes mineral* is digested in the heat with tartaric acid, any oxide of antimony, as well as potassa, which may be present, is removed, and the pure tersulphide of antimony remains; and thirdly, by digesting a mixture of one part of crude sulphide of antimony with one part of pearl ash—crude carbonate of potassa—one and a half of slaked lime, and fifteen of water, in a closed vessel for two hours. During the digestion, a soluble double sulphide of antimony and alkali is formed; and on adding sulphuric acid to decompose the alkaline sulphide, sulphide of antimony falls down; this precipitate is then filtered, washed with sulphide of hydrogen water, and dried.

Pure sulphide of antimony, as prepared by the first method, has a steel-grey color, a shining metallic lustre, and a fibrous crystalline texture; it is brittle, and gives a reddish-black streak upon paper; it is very fusible, but less so than the metal, boils at a high temperature, and partially distils in a current of gas. When heated to whiteness in a crucible, it loses from ten to twelve per cent. of its weight of sulphur; heated in the air, it suffers decomposition, giving off its sulphur in the form of sulphurous acid, and absorbing oxygen, which converts it into teroxide of antimony.

A current of hydrogen gas passed over it at a low red heat completely desulphurizes it, leaving pure metal. This property of hydrogen—that of depriving it of sulphur at a red heat—is possessed also by many metals, of which the most energetic is iron. When exposed with charcoal to a white heat, the sulphide of antimony is reduced to metal.

When the sulphide and teroxide of antimony are fused together, combination takes place, without either of the compounds suffering decomposition.

The following analyses by **Berzelius** and **Thomson** show the composition of pure sulphide of antimony:—

		Centesimally represented.		
	At. weight.	Theory.	Berzelius.	Thomson.
1 Eq. of antimony,	126	72·7	72·8	73·7
3 Eq. of sulphur,	48	27·3	27·2	26·3
1 Eq. of sulphide of antimony,	174	100·0	100·0	100·0

Its chief use, besides its employment as a source for the production of the metal, is for pharmaceutical preparations, chiefly tartar emetic.

Kermes mineral is another sulphide of antimony, united to an alkaline sulphide, and one which has long been known. For a considerable time it was supposed to consist of oxide of antimony united to the sulphides of the metal, until the researches of **Berzelius** and **Rosé** proved it to be a true sulphide of antimony united to an alkaline sulphide. It may be prepared in various ways:—

Firstly, by heating slowly one part of pure carbonate of potassa and two and three-fourth parts of pure sulphide of antimony, in a covered crucible, till the mass fuses, but does not boil; this mixture is to be boiled with water, and filtered; the compound sulphide dissolves out, and, on exposing the solution to the air, precipitates. After the first filtration, the residue is heated with water, or with the clear mother liquid left after a previous deposit of kermes; a further quantity of the compound is dissolved out, which separates from the liquid, as before, as soon as the whole becomes cold. When the boiling solution has been thus treated three or four times in succession, there remains an insoluble substance, composed of a tersulphide and teroxide of antimony, $Sb\,S_3$, $Sb\,O_3$.

A second method is by fusing two parts of metallic antimony, one of sulphur, and three of carbonate of soda; or sixteen parts of the metal, three of sulphur, and thirty-two parts of carbonate of potassa; it may also be prepared by heating a mixture of from three to four parts of cream of tartar—bitartrate of potassa—and one part of sulphide of antimony, in a crucible, till the vapor of decomposed tartaric acid disappears.

The theory of the formation of kermes will be understood from the behavior of the crude antimony with alkalies or their carbonates.

It has been found that no teroxide of antimony is produced by boiling the ordinary sulphide with a dilute solution of alkaline carbonate; and the appended analysis by **Rosé** proves its absence, even when more alkali is present than the tersulphide could saturate. He found the kermes formed under these circumstances to consist of—

	Centesimally.
Antimony,	69·00
Potassium,	2·25
Sulphur,	28·41
Loss,	·34
	100·00

From this analysis, it appears that sulphur is present in the ratio of the formula $K\,S_3$, $Sb\,S_3$; he states, however, that no tersulphide of potassium existed, but a sulphantimoniate of sulphide of potassium, $K\,S$, $Sb\,S_5$, which did not appear to be united with the sulphide of antimony. The kermes, which separates after boiling the crude antimony with alkaline carbonate in excess and cooling the liquid, contains teroxide of antimony; the first portions less, the last more of the oxide. After drying the precipitate the teroxide of antimony becomes more apparent, especially if examined with the microscope, which shows its definite crystalline structure, interspersed with the amorphous flocculi of the kermes. Dilute alkaline solutions hold the teroxide of antimony in solution; stronger lies dissolve a larger quantity of this body, but part with it again as the menstrua cool.

During the action of the alkali, a portion of the sulphur united to antimony is exchanged for the oxygen of the alkali, and a corresponding alkaline sulphide with teroxide of antimony is constituted; hence the hot solutions of the alkali, acting upon the sulphide, always give rise to the hyposulphantimonide of the sulphide of potassium, and hypoantimonide of the oxide of potassium.

The same interchange takes place when sulphide of antimony is fused with the alkaline carbonate in the crucible; a portion of the sulphide is, however, reduced to metal, and the sulphur, which it hitherto held in combination, is transferred to the undecomposed sulphide, which is thereby converted to the state of quinquisulphide. Kermes, formed by boiling the sulphide of antimony with potassa, does not contain, according to **BOOTH**, a trace of the oxide of antimony; but **BRANDE** states, on the authority of **BERZELIUS**, that when the mixture is boiled an alkaline sulphide is formed; and the antimony is converted into teroxide proportionately to the oxygen of the decomposed alkali:—

$$\underbrace{3\,KO}_{\text{Potassa.}} + \underbrace{Sb\,S_3}_{\text{Tersulphide of antimony.}} = \underbrace{3\,KS}_{\text{Sulphide of potassium.}} + \underbrace{Sb\,O_3}_{\text{Teroxide of antimony.}}$$

The sulphide of potassium unites with undecomposed sulphide of antimony, giving rise to a double sulphide of both these metals, $K\,S,\ Sb\,S_3$; and the teroxide of antimony combines with the remaining undecomposed potassa, so that when hot water is added, a solution is obtained, containing the double sulphide of antimony and potassium, and also the oxygen compound of both these metals. As the liquid cools, sulphide of antimony deposits—merely because the solvent power of the sulphide of potassium diminishes by cooling—and carries down with it variable quantities of antimoniated potassa, apparently in combination, as it cannot be removed by washing.

The cold liquor still retains some of the compound sulphide of potassium and antimony, and also the antimoniate of potassa; by adding a dilute acid to this liquid, the sulphide of potassium and water suffer decomposition, being transformed into sulphide of hydrogen and potassa; the antimoniated potassa is likewise broken up, a salt of the alkali with the decomposing acid being formed, by which the sulphide of hydrogen and teroxide of antimony are induced to unite and form a sulphide of that metal which precipitates; this precipitate has a golden yellow color, and is hence called *the golden sulphide of antimony.* It differs from kermes inasmuch as there is no potassium, but more of the teroxide of antimony; and probably it contains an oxysulphide of the metal. The constituents of these two remarkable compounds are contrasted to show their composition, the relative proportions of their components being, however, indefinite :—

Kermes.	Golden sulphide.
Sulphide of antimony.	Sulphide of antimony.
Antimoniated potassa.	Teroxide of antimony.

Kermes mineral, as a medicinal agent, was at one time in high repute on the Continent, where it is still occasionally used in considerable quantities; in England it is scarcely ever prescribed to alleviate human ailments, though used largely as a veterinary medicine. **PEREIRA** states that, when administered in small doses, it acts as a sudorific and liquefacient; in large doses, as an emetic and purgative. It has also been found to act with great benefit as a contra-stimulant, or hyposthenic, in inflammatory diseases, especially in pneumonia. The uncertainty of its operation is, however, a great drawback; even when moderate action follows its use, it is doubtful whether it has any advantage over tartar emetic.

Hydrochloric acid decomposes kermes mineral with the formation of terchloride of antimony, the elimination of sulphide of hydrogen, and the precipitation of sulphur :—

$$\underbrace{K\,S,\ Sb\,S_5,\ Sb\,S_3}_{\text{Kermes.}} + \underbrace{7\,H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{K\,Cl}_{\text{Chloride of potassium.}} + \underbrace{2\,Sb\,Cl_3}_{\text{Terchloride of antimony.}}$$
$$+ \underbrace{7\,H\,S}_{\text{Sulphide of hydrogen.}} + \underbrace{S_2}_{\text{Sulphur.}}$$

Golden sulphide of antimony is completely soluble in hydrochloric acid, with the evolution of sulphide of hydrogen; this behavior shows at once that it is a sulphide, while, like all the other sulphides similarly treated, a solution of terchloride of antimony is formed. When boiled with a solution of bitartrate of potassa, tartar emetic is produced in the liquid, from the solution of the oxide of antimony contained in the precipitate. Its color partly distinguishes it from those sulphur compounds already mentioned. According to **PHILIPS'** analysis, its composition is as follows :—

		Centesimally represented.	
	At. weight.	Theory.	Philips.
1 Eq. of teroxide of antimony,....	153	 13	.... 12·0
5 Eq. of tersulphide of antimony,..	885	 75	.... 76·5
16 Eq. of water,................	144	 12	.... 11·5
1 Eq. of golden sulphide,........	1182	100	100·0

Bitartrate of potassa extracts, according to the preceding, about twelve per cent. of its weight, being the amount of teroxide of antimony present in the sample.

The commercial article is often of a much brighter color than that just described; it is prepared by boiling the sulphide with potassa and ground sulphur, and, after filtering off the liquor, precipitating the compound by means of an acid in the usual way. **REDWOOD** mentions two methods whereby the product is obtained of a similar color to the commercial article: namely, four parts of the black sulphide of antimony are boiled with eight of lime and eighty parts of water, the liquor strained and precipitated by hydrochloric acid in the usual way; or, two parts of the sulphide may be fused in a crucible with four parts of carbonate of potassa and one of sulphur; the residue, when cold, boiled with twenty parts of hot water; the solution filtered and decomposed by a large excess of sulphuric acid.

The medicinal effects of this compound are more active than those of the kermes, on account of the larger proportion of teroxide of antimony which it contains. Its uses are as an alterative in chronic diseases, particularly cutaneous affections, glandular enlargements, rheumatism, and liver complaints.

Oxysulphide of antimony is another of those compounds, prepared almost in the same way as kermes mineral, with the addition of sulphuric acid to the solution obtained after boiling the sulphide of antimony in the alkaline liquid; the action of the alkali being productive of a hyposulphantimonide of the alkali metal, and likewise a compound of the alkali and oxide of antimony, which are dissolved in the liquid, and also a portion of tersulphide. These are reacted upon as under:—

$$\underbrace{3\,(K\,S, Sb\,S_3)}_{\text{Hyposulphantimonide.}} + \underbrace{K\,O}_{\text{Potassa.}} + \underbrace{Sb\,O_3}_{\text{Teroxide of antimony.}} + \underbrace{4\,H\,O, S\,O_3}_{\text{Sulphuric acid.}} =$$

$$\underbrace{4\,(K\,O, S\,O_3)}_{\text{Sulphate of potassa.}} + \underbrace{3\,Sb\,S_3, Sb\,O_3}_{\text{Golden sulphide.}}\ \underbrace{H\,O + 3\,H\,S.}_{\text{Sulphide of hydrogen.}}$$

In the preceding decomposition, the whole of the sulphide of potassium and potassa which retain the teroxide and tersulphide of antimony in solution, are converted into a neutral sulphate, with the elimination of sulphide of hydrogen, and the teroxide and tersulphide in conjunction fall down.

Should the liquor, before the addition of the sulphuric acid, contain a pentasulphide of the metal, arising from the absorption of oxygen from the air, it will be precipitated in that state by acids, and hence the composition of the golden sulphide is often variable.

TEROXIDE OF ANTIMONY.—This compound was known to BASIL VALENTINE, who called it *flores antimonii*. In commerce it bears the several appellations of *protoxide*, *sesquioxide*, and *flowers of antimony*. It may be prepared in several ways—first, by heating metallic antimony to the point of its combustion; it burns with a bluish light, and if the crucible be reclined on one side, to admit a current of air, small acicular crystals of teroxide will be observed on the upper part; secondly,—by adding metallic antimony in powder to sulphuric acid, evaporating the liquid to dryness, and then washing the dry mass, first with water, and next with a weak solution of carbonate of soda, for the purpose of removing the last portions of sulphuric acid; after completely washing the residue, a white powder remains, which is teroxide of antimony; thirdly,—by digesting finely-ground sulphide of antimony in about four times its weight of hydrochloric acid, terchloride of antimony is formed and sulphide of hydrogen escapes with effervescence, the former of which is decomposed by carbonate of soda into teroxide of antimony, which precipitates, while carbonic acid is liberated, and the soda is converted into chloride of sodium by the chlorine of the antimonial compound.

Subjoined is the symbolical arrangement of these decompositions:—

$$\underbrace{Sb\,S_3}_{\text{Tersulphide of antimony.}} + \underbrace{3\,H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{Sb\,Cl_3}_{\text{Terchloride of antimony.}} + \underbrace{3\,H\,S}_{\text{Sulphide of hydrogen.}}$$

$$\underbrace{Sb\,Cl_3}_{\text{Terchloride of antimony.}} + \underbrace{3\,Na\,O, C\,O_2}_{\text{Carbonate of soda.}} = \underbrace{Sb\,O_3}_{\text{Teroxide of antimony.}} + \underbrace{3\,Na\,Cl}_{\text{Chloride of sodium.}} + \underbrace{3\,C\,O_2}_{\text{Carbonic acid.}}$$

The precipitated teroxide is collected upon a filter, washed well with water, and dried. For pharmaceutical purposes, the Dublin college recommends the treatment of twenty parts of the powdered sulphide of antimony with one hundred parts of hydrochloric acid and one of nitric acid; the acid and powder must be slowly brought together, and a gentle heat applied for some time, which may be afterwards increased, and the solution left to digest as long as any effervescence or escape of sulphide of hydrogen is observed; and then the whole is to be boiled for an hour, the liquor filtered when cold, and the filtrate received in a vessel containing one gallon of cold water, which precipitates the basic terchloride of antimony—

$$\underbrace{6\,Sb\,Cl_3}_{\text{Terchloride of antimony.}} + \underbrace{15\,H\,O}_{\text{Water.}} = \underbrace{(Sb\,Cl_3, 5\,Sb\,O_3)}_{\text{Oxychloride of antimony.}} + \underbrace{15\,H\,Cl}_{\text{Hydrochloric acid.}}$$

The oxychloride is collected, and washed with water till the washings cease to evince an acid reaction with litmus paper. During the washing of the precipitate the following change occurs:—

$$\underbrace{(Sb\,Cl_3, 5\,Sb\,O_3)}_{\text{Oxychloride of antimony.}} + \underbrace{3\,H\,O}_{\text{Water.}} = \underbrace{6\,Sb\,O_3}_{\text{Teroxide of antimony.}} + \underbrace{3\,H\,Cl}_{\text{Hydrochloric acid.}}$$

showing that the water is decomposed, its oxygen being retained by the antimony, which yields the chlorine combined with it to the hydrogen, forming hydrochloric acid.

DUMAS directs the preparation of teroxide of antimony to be conducted as follows:—Heat pulverized antimony in a shallow vessel exposed to the air; when the oxidation has advanced, the metal takes fire and becomes incandescent, antimonious acid—mixed, however, with some of the metal—being produced; the whole of the compound is now transferred to a crucible, in which it is heated to fusion, when the antimonious acid is reduced to the state of teroxide by the excess of metal, which is found, with the fused mass, in a button at the bottom.

Teroxide of antimony is a white powder, fusible, and volatile at a red heat; when heated in close vessels it suffers no change, but is partly sublimed, and condenses in acicular crystals on the cover, or upper part of the pot. Sometimes, however, the crystals are found in octahedrons.

If the teroxide be kept in fusion, with contact of air, it is converted into a higher state of oxidation; but if the air be excluded, it concretes into a silky crystalline mass, presenting a greyish appearance.

Water dissolves traces of teroxide of antimony, as proved by the solution assuming a yellow color when treated with sulphide of hydrogen. If heat be applied to this liquid, and a slight addition of hydrochloric acid be made, the orange-red sulphide of antimony falls down. Nitric acid and chlorate of potassa rapidly convert the teroxide into a higher degree of oxidation; sulphur decomposes it in the heat into a sulphide, with the formation of water; and when heated to redness with charcoal, metallic antimony is obtained. Tartaric acid readily dissolves the oxide; bitartrate of potassa acts similarly, producing in either case tartar emetic. On boiling recently precipitated teroxide of antimony with a concentrated solution of potassa, a compound body of both oxides is formed, which falls down in the form of a greyish powder, or white crystalline grains, difficultly soluble. With soda and ammonia similar bodies are produced.

Teroxide of antimony is composed of

	Atomic weight.	Contesimally.	
		Theory.	Berzelius.
1 Eq. of antimony,....	129	84·316	84·319
3 Eq. of oxygen,.....	24	15·384	15 681
1 Eq. of teroxide,.....	153	100·000	100·000

Terchloride of Antimony—Butter of Antimony—is used to some extent in medicine, chiefly as a caustic, and as such takes its place among the antimonial preparations. It is the principal ingredient in some patent medicines lately offered to the public, which are said to be next in efficacy to the *elixir vitæ*. It will be necessary, therefore, to give here a short description of its preparation and properties.

On dissolving sulphide of antimony in hydrochloric acid, as before explained, terchloride of antimony is formed, with the evolution of sulphide of hydrogen. The action of the hydrochloric is greatly accelerated by mixing with it a small proportion of nitric acid. When the solution thus obtained is evaporated, the butter of antimony remains in the solid state. To prepare the pure salt, Berzelius recommends that the hydrochloric acid solution of the terchloride should be evaporated in a porcelain dish, till it begins to crystallize on the dish being placed in a cold situation; the concentrated liquid is then transferred to a retort, and distilled until a drop of the liquid solidifies upon a cold surface; at this point the receiver is changed, and the remaining portion of the charge collected as pure.

It is white, semitransparent, crystalline, of a buttery consistence, and deliquescent in the air; heated to about 162° Fahr. it flows like oil, and boils at 446°.

When added to water it gives a bulky white precipitate of oxychloride of antimony—$Sb\,Cl_3 + 5\,Sb\,O_3$—while the supernatant liquor is charged with hydrochloric acid: tartaric acid dissolves the oxychloride; hence, if that acid be present previous to the addition of water, no precipitate is produced.

Terchloride of antimony affords, with all the other reagents, similar reactions to those which distinguish the other salts of this metal.

Its composition is—

	Atomic weight.	Centesimally.	
		Theory.	Rosé.
1 Eq. of antimony,............	129 ..	54·83 ..	53·27
3 Eq. of chlorine,............	106·5 ..	45·17 ..	46·73
1 Eq. of terchloride of antimony,	235·5	100·00	100·00

Besides being used as a caustic, it is employed in the arts, especially by gunmakers, for the purpose of giving a yellow color to gun barrels, and is called *bronzing salt*. It is used for this purpose in the state of solution, mixed with olive oil, and rubbed over the iron slightly heated, which is then exposed to the air till the desired color is obtained. Sometimes, to quicken the effect, nitric acid is added. When bronzed, the surface of the iron is polished by a burnisher, or by wax, or by varnish composed of two ounces of shell-lac and three drachms of dragon's-blood dissolved in two quarts of spirit of wine. The bronze color is due to sesquioxide of iron, and hence other metals often containing copper are employed.

Quantitative Estimation of Antimony by Analysis.—As those engaged in docimacy should be able to judge of the quality and nature of all substances appertaining to metallurgy, at least of those compounds with which they are immediately engaged, the mode of analysis and assay of the metals and their principal ores, will be given as they come under consideration.

The per centage of antimony in a mineral may be estimated from the amount of the *sulphide of antimony*, the *antimonious acid*, or of the *pure metal*, which it produces when operated upon with appropriate reagents. A solution of the metal is obtained by treating the ore with strong hydrochloric acid, containing some nitric acid—in case of the absence of silver—and diluted with water; should any turbidness ensue, tartaric acid must be added to dissolve it, or, if the addition of this acid would interfere with the estimation of any other metal, hydrochloric acid is employed to effect the same purpose. Sulphide of hydrogen is next transmitted through the liquid, until the solution acquires the strong odor of the gas; if antimony is the only metal present, the beaker or flask holding the precipitate may be placed on a hot sand-bath till the excess of sulphide of hydrogen is expelled.

By this means the small quantity of sulphide of antimony retained in solution by the excess of the gas is set at liberty. The menstruum is then filtered through a dried and tared filter, washed with water, desiccated at 212° till the weight remains constant, then weighed. As the antimony in solution is often in a higher state of oxidation than the teroxide, especially if nitric acid has been employed, and as more or less of the sulphide of hydrogen is decomposed by the free acid of the solution before precipitation, the sulphide of antimony produced contains an excess of sulphur, so that from its weight the true quantity of metal cannot be deduced. In this case the dry compound is detached as much as possible from the filter, and the latter reweighed with any adhering portions; the difference of weight equals the quantity of sulphide taken. This sulphide is introduced into a flask, and strong nitric acid, in successive small portions, added to prevent any loss of the substance by the too energetic operation of the acid. After the action has ceased, hydrochloric acid is added to dissolve the whole of the antimonious acid, formed by the action of the nitric acid upon it.

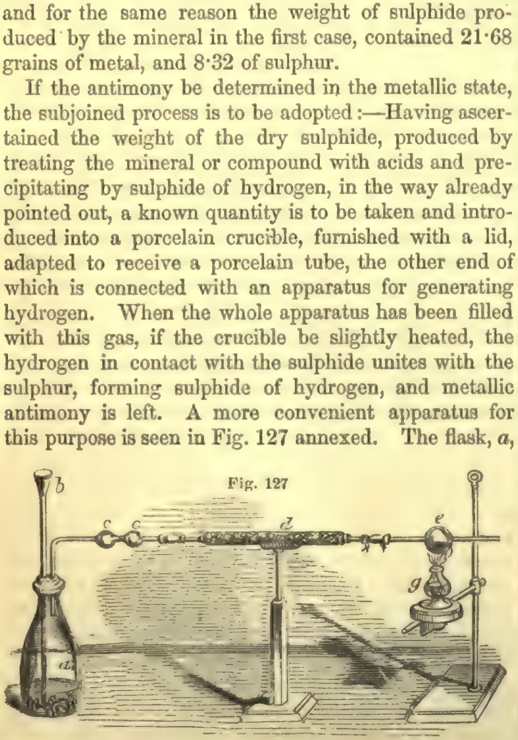
If dilute nitric acid had been taken in the first instance, there would be a certain quantity of sulphide of hydrogen formed, and which, by its escape, would cause an error in the result. After the whole of the sulphide has been oxidized into sulphuric acid and antimonious acid, and any portions of the latter which might have precipitated, redissolved by tartaric or hydrochloric acid, a solution of chloride of barium in excess is poured into the liquid; this occasions a deposit of sulphate of baryta, which, after being filtered, is dried, ignited, and weighed. From the amount of sulphate of baryta, that of the sulphur in the sulphide of antimony operated upon is calculated, and by deducting this from the weight of the sulphide of antimony, the weight of the metal is indirectly obtained.

In case too much tartaric acid had been used, before precipitating the sulphuric acid by the chloride of barium, some tartrate of baryta is likewise thrown down, and cannot be removed by washing. To ascertain, therefore, the real weight of the sulphate of baryta, the precipitate of mixed sulphate and tartrate, after being heated to redness and weighed, is treated in the crucible, or a small beaker, with a few drops of strong nitric acid, heated, and filtered, the residue washed well with hot water, dried, and reweighed. If the weight of sulphate, as now ascertained, corresponds with that which was previously found, no tartrate of baryta was present, but, should a difference be found, it arises from the tartrate of baryta which was deposited in conjunction with the sulphate, but which was decomposed during the ignition, leaving carbonate of baryta, a salt easily soluble in hydrochloric or nitric acid. The latter weighing gives the true amount of sulphate of baryta.

That the calculation of the analysis may be better understood, the following is an example:—If the weight of ore taken furnished a precipitate of mixed sulphides of antimony weighing thirty grains, twenty of which, when treated with nitric acid in the manner already described, yielded, on being precipitated with chloride of barium, a quantity of pure sulphate of baryta, the weight of which may be supposed to be forty grains—since, in round numbers, one hundred and seventeen grains of the baryta salt contain sixteen of sulphur, it follows, that forty grains will afford 5·55 grains of this element, which were derived from the sulphide of antimony; hence, it appears that the twenty grains submitted to analysis consist of 5·55 of sulphur, and 14·45 grains of metal, and for the same reason the weight of sulphide produced by the mineral in the first case, contained 21·68 grains of metal, and 8·32 of sulphur.

If the antimony be determined in the metallic state, the subjoined process is to be adopted:—Having ascertained the weight of the dry sulphide, produced by treating the mineral or compound with acids and precipitating by sulphide of hydrogen, in the way already pointed out, a known quantity is to be taken and introduced into a porcelain crucible, furnished with a lid, adapted to receive a porcelain tube, the other end of which is connected with an apparatus for generating hydrogen. When the whole apparatus has been filled with this gas, if the crucible be slightly heated, the hydrogen in contact with the sulphide unites with the sulphur, forming sulphide of hydrogen, and metallic antimony is left. A more convenient apparatus for this purpose is seen in Fig. 127 annexed. The flask, *a*, contains water and a few bars of zinc; sulphuric acid is poured in through the funnel, *b*, in order to generate the gas, which escapes by a tube opening just below the cork of the flask, and which is provided with two bulbs, *c c*, where the greater part of the moisture carried away by the gas is condensed. To dry the hydrogen completely, it is conducted through another large tube, *d*, filled with fragments of chloride of calcium, and thence into the bulb, *e*, holding the substance to be reduced. All the bulbs and tubes should be of hard German glass. Before commencing the experiment, the bulb, *e*, with its glass tubes attached, should be thoroughly cleaned, dried, and weighed, and the sulphide of antimony then introduced, taking the precaution that none of the substance remains in the tubes; if it should happen that a little adheres, a feather will push it forward to the bulb. The bulbed tube and its contents are now reweighed, and the increase of weight is the quantity of the compound submitted to experiment. The various parts of the apparatus are next well connected by means of caoutchouc tubes, as seen in the figure, and the hydrogen generated; as soon as the apparatus is filled with the gas, a gentle heat is applied by means of a spirit-lamp, *g*, to the bulb containing the substance, till the reduction is completed. If the compound consists of tersulphide of antimony, scarcely any sulphur is sublimed during the reduction, as it passes off in the form of sulphide of hydrogen; but should the higher sulphurized compounds of antimony be present, sulphur will be sublimed at the same time that the remaining part unites with the hydrogen and escapes. The sublimed sulphur is expelled by bringing the heat of the lamp gradually towards that part of the tube where it is deposited. When it is observed that no more sulphur condenses in the tube, and that sulphide of hydrogen ceases to be evolved from the extremity, the apparatus is allowed to cool, but the current of hydrogen is still maintained. As soon as the apparatus is perfectly cold, it is taken to pieces, the bulb-tube, *e*, wiped clean and weighed; the difference between the weight of the bulb-tube and substance before the experiment, and that which is now obtained, is the amount of sulphur in the sulphide submitted to reduction, and the difference between the weight of the empty tube, and its weight after the reduction, is the weight of the metal yielded by the sample operated upon; hence, as in the case of the sulphate of baryta, the per centage of antimony in the sample is calculated from this determination. Considerable care must be exercised in the reduction of the sulphide of antimony by hydrogen gas, in order to arrive at accurate results: indeed, it is almost impossible to prevent the sublimation of a small portion of metallic antimony, if the heat applied be at all higher than the required degree; and on the contrary, if it be too feebly applied, part of the sulphur remains without being expelled, and for this reason the weight of antimony obtained is too great.

Fig. 127



Another source of error is, that the hydrogen carries portions of the metal with it in combination, in the form of terhydride of antimony, which may be proved by igniting the gas as it is discharged from the end of the tube, when very slight but perceptible fumes of teroxide of antimony will be observed; and if a cold porcelain surface be held over the flame, the metal will deposit upon it in the form of a black spot. Hence, in most analyses, the operator invariably finds a little less of metal and more sulphur than the compound really contains, as the sulphur is calculated from the loss which the body suffers during heating. When a strictly accurate determination is not so much sought, with ordinary care the method here laid down answers the purpose. If the heat be applied slowly at first, and then kept incipient till the greater part of the sulphur is expelled, raising it after that time till the bulb becomes slightly red, the loss of antimony will not exceed half a per cent. The reduced metal does not fuse into a globule, but remains in the form of small metallic grains; and if the heat applied during the time the hydrogen is forced through the apparatus be slow and continuous, the reduced metal presents crystalline facets, the lustre of which causes the antimony to appear blacker than when it is reduced under the influence of a stronger heat.

When antimony is alloyed with other metals, or associated with them in mineral substances, its amount may be determined—except when united to tin—by dissolving the substance in nitric acid, or in aqua regia containing an excess of nitric acid; the antimony by this treatment is converted into teroxide of antimony, which precipitates, while the other oxides are dissolved in the liquid. Before the whole of the antimony is thrown down, however, it is necessary to decompose any terchloride that may be formed—when aqua regia has been used as the solvent—by evaporating the liquid with an excess of nitric acid. The residue is then thrown upon a filter and washed with water, dried, and its weight determined, after which a portion is taken, and reduced by hydrogen in the way already described.

This method does not yield strictly accurate results, on account of the precipitated teroxide of antimony not being perfectly insoluble in nitric acid, and, therefore, the filtrate and washings always contain some traces of antimony; yet, for technological purposes, the results obtained are sufficiently correct.

In scientific investigations, the solution of the metals should be treated with ammonia in slight excess, then with a strong solution of sulphide of ammonium, containing an excess of sulphur, which dissolves the antimonial body, leaving the sulphides of the accompanying metals. By filtering off the solution, and washing the residue, first with dilute sulphide of ammonium, and then with water, the whole of the antimony is removed; the washings and filtrate are now mixed, hydrochloric acid added in slight excess, and a gentle heat applied as long as sulphide of hydrogen is evolved, by which the sulphide of antimony is thrown down; it is to be collected on a dry tared filter, washed with a little sulphide of hydrogen water, dried at 212° till the weight remains constant, and then reduced in the way already explained. Antimony is removed by this process from lead, silver, mercury, bismuth, copper, iron, nickel, cobalt, and manganese.

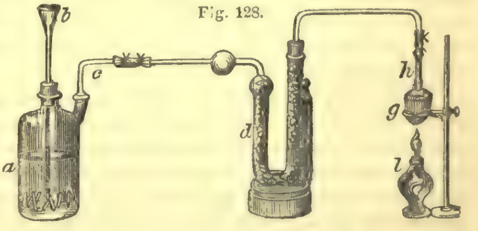
If antimony has to be separated from tin, ROSÉ recommends the appended process:—When both metals are alloyed, he treats the mass cautiously with nitric acid, and after the violent oxidation has terminated, evaporates the liquid at a gentle heat. When perfectly dry, the mixed oxides thus obtained are to be fused in a silver crucible, over an Argand lamp, with an excess of hydrate of soda; the fused substance is to be softened with a large quantity of water, gently warmed, and the antimoniate of soda allowed to subside. After the liquor becomes perfectly cold, the clear solution is filtered off, and the precipitate retained still in the beaker is treated a second time with water, which is filtered from it as before.

In this way the whole of the stannate of soda is removed, and antimoniate of soda left. As soon as the liquid remains opaque, it is a sign that the whole of the tin salt is dissolved. If the opaque liquid containing the antimoniate of soda were thrown upon the filter, it would pass through owing to its very minute state of division, but upon the addition of a small quantity of a dilute solution of carbonate of ammonia, the liquor quickly clarifies, and may be passed through without fear of the filtrate appearing turbid; the edulcoration should not be continued too long with the carbonate of ammonia, as small quantities of the teroxide are dissolved by this reagent.

The moist antimoniate is now treated in a beaker glass, with a mixture of tartaric and hydrochloric acids, which readily dissolves it; the solution is next filtered, and the paper washed with a dilute solution of the acids, in order to remove any traces of the substance that may have remained adhering to the paper. Sulphide of hydrogen gas is then passed into the liquid, until the whole of the antimony is converted into orange-red sulphide, and the liquor evolves a strong odor of the gas; the beaker is then covered, and left in a moderately warm place on the sand-bath till the free sulphide of hydrogen is expelled, after which the precipitate is collected upon a dry tared filter, exsiccated and weighed, and the proportion of sulphur and metal ascertained by either of the foregoing methods.

ROSÉ reduces the sulphide of antimony in an apparatus such as the annexed—Fig. 128: *a* is a bottle, containing zinc and water; *b*, a funnel-tube descending through the cork nearly to the bottom of the bottle; *c*, a second bent tube entering the bottle through the perforated cork, below which it opens; this tube carries the gas to the chloride of calcium tube and bulb, *d*, where it is divested of moisture. The tube, *e*, passing through the cork of the chloride of calcium tube, conveys the dry gas to the crucible, *g*, containing the body to be reduced. A lid is affixed to this crucible, through which a small porcelain tube, *h*, passes, and which is connected to the pipe, *e*, by a piece of caoutchouc tubing. Before the experiment commences, the crucible with the lid and its tube is balanced, and then the substance introduced, and the whole reweighed; the dif-

Fig. 128.



ference in the two weighings is that of the body taken. All the connections of the apparatus are now made airtight, and the crucible attached; hydrogen is generated in the bottle, *a*, by pouring sulphuric acid down the funnel tube, *b*, and when the whole apparatus becomes filled with the gas, heat is applied by means of a spirit-lamp, *l*, to the crucible, taking all the precautions previously mentioned. When it is observed that no more sulphide of hydrogen is evolved from the end of the tube, the heat is removed, but the current of hydrogen is maintained during the cooling of the apparatus, after which it is taken asunder, and the crucible with its contents weighed. The calculations are the same as those mentioned in the preceding experiment.

ARSENIC is a metal which is associated with antimony in several ores. The annexed method serves for their separation:—Having dissolved the ore or alloy in aqua regia, sulphides of antimony and arsenic are to be obtained by saturating the solution with ammonia, and then adding sulphide of ammonium containing an excess of sulphur; the menstruum is allowed to digest for some time, then filtered, and hydrochloric acid added to the filtrate in slight excess, to precipitate the dissolved sulphides. The precipitate is collected upon a dry tared filter, washed with water impregnated with a little sulphide of hydrogen, and dried in the water-bath till all moisture is expelled, after which it is weighed. Having found the weight of the mixed sulphides, a portion is taken, and the amount of sulphur in it ascertained by treating a known quantity with aqua regia, till all the sulphur is oxidized, and then with chloride of barium, tartaric acid being previously added to prevent the precipitation of any basic terchloride upon diluting with water. The precipitated sulphate of baryta is treated as before directed.

Another portion of the mixed sulphides is introduced into the bulb tube—Fig. 127—and a stream of hydrogen gas passed over it, while a proper heat is applied by the lamp; all the sulphide of arsenic, with the excess of sulphur, is expelled, leaving sulphide of antimony, which is to be weighed.—*Noad.*

This method, according to ROSÉ, gives very accurate results when performed with ordinary care. From the loss sustained by the weight of sulphide taken in the last experiment, and which is sulphur and arsenic, the proportion of sulphide of antimony is known; and since the amount of sulphur in the entire substance has been already ascertained, by deducting it from the combined weight of the sulphur and arsenic, as before ascertained, the difference is the arsenic.

DRY ASSAY OF ANTIMONIAL ORES.—All the ores of antimony, for the purpose of assay, may be divided into two classes—those in which the metal is combined with oxygen or chlorine, and in which little or no sulphur is present; and those compounds of sulphur and the metal, which include all those other minerals compounded of antimony, and other metals united with sulphur.

All the ores belonging to the first class are very easily reduced—provided no earthy or silicious matters are present—by simply heating them to redness with finely divided charcoal, and the assay may be conducted in an earthen crucible; but as antimony is so readily volatilized, care must be taken that the heat is not too high during the reduction. If the ore contain calcareous or silicious impurities, it is necessary to mix it either with three parts of black flux, or one of carbonate of soda, and one-fourth part of charcoal finely ground. In this case the lining of the crucible with charcoal powder may be dispensed with, as it may be introduced at once into the fire, and left there till the content is in a tranquil state of fusion; it is then to be withdrawn, and gently tapped against some hard substance while hot, to cause the small globules of antimony to unite and form one button at the bottom.

The crucible is broken as soon as it gets cold, and the metallic button at the bottom carefully freed from adhering matter, by gently tapping it with the hammer, brushing off dust, or other adhering matter, and weighed. Unless great delicacy of manipulation be observed when detaching the slag, portions of the metal will be removed on account of the brittleness of the antimony rendering it liable to the detachment of small particles, which, of course, would be so much loss. Substances, principally consisting of teroxide of antimony, but which contain small quantities of sulphur, may be analysed by the foregoing method; for as the sulphide yields to the black flux just half its combined antimony, a very small portion only can be retained in the slag. When oxide of iron is present in abundance, this metal is liberated simultaneously with the antimony, and both uniting, form an alloy, which, if weighed as being entirely antimony, will afford wrong results.

Ores of the second class offer more difficulties than those just described. Their assay may be performed either by first roasting the sulphide, and subsequently fusing the oxide produced with black flux, or by directly treating the mineral, reduced to an impalpable powder, with finely divided metallic iron or iron scales, and a little black flux, at an elevated temperature.

As the sulphide of antimony is very fusible and volatile, it requires much care and attention to roast it thoroughly, in order to expel the sulphur, and form the teroxide of the metal; to be successful, the temperature should be moderate, and the mass kept stirred with an iron rod or wire, as long as any sulphurous vapor rises. When these cease to be evolved, the residue is fused with three parts of black flux in the usual way, by which a button of antimony is obtained.

Sulphide of antimony is reduced with facility, by fusing it with minutely divided metallic iron, such as filings, *et cetera*. The sulphide of iron resulting from the decomposition, has a specific gravity closely corresponding with that of metallic antimony, and hence it becomes difficult to remove the metal, unless the contents of the crucible be kept fluid for a considerable time at a moderate heat. When this precaution has been taken, two distinct masses are observed on breaking the crucible; the bottom one, which is antimony, being of a white color, and crystallized in plates, while the other has a bronze yellow tint, and is composed of sulphide of iron, containing a small proportion of metallic antimony. The quantity of antimony is ascertained by carefully detaching it from the sulphide of iron, and weighing.

Accurate results are not, however, obtained by this method, as the prolonged heat, however carefully attended to, sublimes some of the metal. In reducing sulphide of antimony by metallic iron, it is necessary to proportion the weight of iron used to the sulphur in the ore, as, from the great tendency of the antimony to form an electro-negative element, it would unite with the excess of iron and form an antimonide of iron, which would render the remainder impure; it is likewise necessary to have the iron as free as possible from rust or sesquioxide, in order that it may effect the decomposition as rapidly as possible, for then the less antimony would be lost by sublimation. Cast-iron cannot be used to decompose sulphide of antimony, as sulphur has but very little effect upon it, unless at a high temperature, and then the slag adheres so tenaciously to the reduced antimony, that it cannot be accurately detached.

Much of the inconvenience attending the reduction of the sulphide of antimony by means of iron, may be avoided by mixing with the reducing agent a carbonate of soda, which lessens the density of the slag and increases the fusibility of the mass. To gain this point, the alkali is mixed with the antimonial body, and the mixture subjected to heat till it liquefies, and when this happens, the proper weight of iron is introduced; metallic antimony readily separates, and the slag, which is now a double sulphide of iron and sodium, is as fusible as was the double sulphide of metal and antimony previous to decomposition; such a slag affords great facility for the metal assuming the form of a globule or button at the bottom of the crucible or cupel. Similar changes take place when the sulphide of antimony, iron, and carbonate of soda are mixed at once, previous to the application of heat. Although the carbonate of soda favors the decomposition of sulphide of antimony by iron, yet great care must be taken when it is employed, particularly when the iron is used only in proportion to form sulphide, with the sulphide in combination with the antimony, as it produces a slag containing a large quantity of antimony. For reducing pure sulphide of antimony, the best and most economical amount is from forty-five to fifty parts of the alkaline carbonate, with forty-two of iron, and five of finely divided charcoal for every hundred parts of the ore. On subjecting this mixture to heat in a crucible lined with charcoal, it readily affords from sixty-five to sixty-seven per cent. of regulus of antimony. Oxide of iron may be used in this operation, but the charcoal must be added in larger proportions.

When iron scales are used, it is necessary to take forty parts to every hundred of the ore, and this mixture, on being fused with one hundred parts of carbonate of soda and fifteen of charcoal, affords between sixty-five and sixty-seven per cent. of metal.

Cyanide of potassium has been lately introduced into the assaying of antimonial sulphides with decided advantages over the other methods, as the heat required to effect the reduction is much lower, and the operation is performed quicker than by any of the foregoing processes.

Mitchell recommends four parts of the cyanide to a hundred of the sulphide, and upon gently heating the mixture in an earthen crucible for a short time, the metallic antimony is obtained.

The dry assay of antimonial combinations gives only a wide approximation to the truth; hence, when strict accuracy is required, recourse must be had to the humid analysis.

The importation of antimony ore annually averages about one thousand tons, which is chiefly from Borneo. The price varies, according to its richness and supply, from £10 to £14 per ton, and that of metallic antimony from £38 to £48 per ton.

ARSENIC.—*Arsenic*, French; *arsenik*, German; *arsenicum*, Latin.—The word arsenic occurs first in the writings of Dioscorides, and some of the authors who lived about the commencement of the Christian era. In those works the word denotes a reddish-colored mineral, composed of arsenic and sulphur, used medicinally by the ancients, and also in painting.

This substance is peculiar to the mineral kingdom. It is found in the elementary state, and in combination with oxygen, sulphur, and other bodies.

The distinct metallic characters of arsenic were discovered by Brandt in 1773, who gives the first accurate process for procuring it. He mixed white arsenic—arsenious acid—with potassa and chloride of ammonium, and fused the mixture in a well-luted crucible. Its properties were further investigated by Macquer, in 1746; by Munnet, in 1773; and by Bergmann, in 1777; but the latter took many of his facts from Brandt's paper.

To the labors of these philosophers, and likewise to those of Scheele, science and art are indebted for almost all that is known of the properties of this element.

Its general chemical relations are such as to place it rather among the simple acidifiable bodies than among the metals, for it forms no salifiable base with oxygen, but constitutes acids; it possesses, however, the lustre and opacity of a metal, and conducts electricity.

There are two native compounds of it with oxygen, namely, arsenious and arsenic acid, the latter being found with bases, forming arseniates. Orpiment and realgar, two of its sulphides, are also met with in the mineral kingdom. Some time ago, M. Tripier detected arsenic in the mineral waters of Meskoutine, in Algiers, and Walchner has found that small quantities of arsenic always accompany iron, and frequently influence its quality. It is often found in combination with metallic sulphides, especially with the sulphide of iron, constituting arsenical pyrites. It will be well to append the principal modifications of this element:—Native arsenic, arsenious acid, arsenic glance, realgar, orpiment, arsenical pyrites, bright white cobalt, tin white cobalt, bismuth cobalt ore, nickel ochre, polybasite, red silver, and various other compounds; as arsenic acid in arseniate of copper, of which several varieties are known; in euchroite, kupferschaum, erinite, scorodite, and in various other combinations.

The metal is easily prepared in the laboratory, by mixing one part of pure arsenious acid with three of black flux in a crucible, on which another of a similar shape is inverted as a head, and applying a moderate heat, either in a furnace or over a lamp. By keeping the cover as cool as possible, the metal will be found in the course of a short time sublimed, and adhering to the interior of the crucible, in the shape of a glassy coating of a brilliant metallic appearance.

Charcoal, or oil, may be substituted for the black flux if requisite, and similar results are obtained upon distilling from a retort of hard glass.

Arsenic is of a bluish-white color and crystalline texture. It is the most volatile of all the metallic bodies, and is so brittle that it may be easily reduced to a fine powder by trituration in a mortar. Kept in water, it suffers no alteration; but when exposed to the air, it soon loses its lustre, becomes black, and falls to powder. It volatilizes—seemingly before fusing—at a temperature of about 360° Fahr. When exposed to a moderate heat in contact with air, it sublimes in the form of a white powder, and at the same time emits a most characteristic alliaceous odor. If the heat be increased, it burns with a pale blue flame—arsenic, indeed, is one of the most combustible of the metals.

The substance which sublimes was formerly called arsenic, or white arsenic, and is still known by those names in the commercial world; but this is now denominated arsenious acid. It is seldom prepared by chemists, because it exists native, and is often procured in great abundance during the extraction of the metals from their ores.

ORFILA states that metallic arsenic, when swallowed, is capable of acting as a powerful poison, probably by being oxidised into arsenious acid.

The specific gravity of arsenic is 5·96, and of its vapor, 1·0362, air being unity.

Heated in an atmosphere of oxygen gas, arsenic burns with a bluish flame; with chlorine it ignites spontaneously, producing a brilliant white flame, and arsenious acid. It is soluble in nitric acid and in aqua regia, and is converted by this treatment into arsenious or arsenic acid, according to the more or less prolonged action of the solvents. It enters into fusion with most of the metals, and, by this union, renders those which were malleable, more brittle, and those before difficultly fusible, more easily melted; it also confers a brightness upon the alloy, which often renders its presence in small quantities desirable.

The metal is prepared on the large scale by subjecting native arsenic, or arsenical iron, to sublimation in earthenware retorts, to which are attached receivers, wherein a piece of rolled sheet-iron is generally placed to collect the whole or greater part of the sublimate. The other methods do not differ from the preceding process for reducing arsenious acid, except that, on the large scale, the product is impure.

Those compounds of arsenic which are the objects of manufacture, and which are applied, to a considerable extent, in the arts, are arsenious acid, and its combinations with other metallic bases, such as copper, cobalt, chromium, *et cetera;* sulphides of the metal, such as orpiment and realgar, and some few others which will be described in the succeeding pages.

ARSENIOUS ACID.—*Acide arsenieux*, French; *arseniksäure*, German; *acidum arseniosum*, Latin.—Arsenious acid, white arsenic, and white oxide of arsenic, are synonymous.

This compound is formed, as previously stated, when arsenic is heated in the open air; it sublimes in white fumes, and, when collected, constitutes arsenious acid. It is usually in the form of a compact white cake; but it may also be obtained crystallized in octahedrons.

It has an acrid taste, which ultimately leaves an impression of sweetness, and it is one of the most virulent of poisons. Arsenious acid is composed of one equivalent of arsenic and three equivalents of oxygen, as shown by the analyses of MITSCHERLICH and BERZELIUS:—

		Centesimally represented.		
	Atomic weight.	Theory.	Mitscherlich.	Berzelius.
1 Eq. arsenic,........	75 ..	75·76 ..	75·730 ..	75·782
3 Eq. oxygen,........	24 ..	24·24 ..	24·270 .	24·218
1 Eq. arsenious acid,..	99	100·00	100·000	100·000

It is prepared in several other ways besides those previously given. The readiest way to proceed in the laboratory will be to dissolve the metal in nitric acid, and evaporate the liquid to perfect dryness to expel the whole of the nitric acid; the residue should be washed with a little water, in order to remove any adhering nitric acid, after which it is dried, and retained carefully for use.

Arsenious acid is soluble in boiling water to a moderate extent, but considerably less so in cold; it is also soluble in alcohol and oils. Regarding the solubility of arsenious acid, GUIBOURT found that the vitreous acid required 104·17 parts of water at 60° Fahr., and the opaque 80 parts. Boiling water dissolved 9·68 of the former, and 11·47 parts of the latter; the solutions, upon being cooled at 60°, retained 1·78 of the vitreous, and 2·9 of the opaque. This authority further states, that the color of litmus paper was only faintly tinted red by the solution of the vitreous, and not at all by that of the opaque acid, but paper slightly reddened was turned blue by it; both solutions, however, communicate a feeble acid reaction to blue litmus paper.

Arsenious acid is found in two distinct conditions—crystallized and amorphous. The crystallized acid often assumes two forms; the octahedron and tetrahedron. —Figs. 129 and 130. WÖHLER has observed that the acid assumes the form of hexahedral plates, derived from the right rhombic prism; hence it appears to be dimorphous, which seems connected with the peculiarities of the opaque and vitreous state of the acid.

Fig. 129.

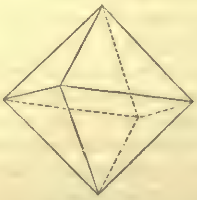
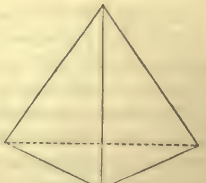


Fig. 130.



Vitreous arsenious acid, when recently prepared, is in the form of large, glassy, colorless, transparent cakes; it is sometimes of a yellowish color, and in concentric laminæ formed by successive sublimations. By exposing these transparent cakes to the air, they are readily covered with a white coating, and lose their former transparency. This change is gradually extended to the centre, so that the fracture has an enamel-like appearance; occasionally, the cakes crumble down into a friable mass. The reason of this change has been ascribed by **KRUGER** to the absorption of water, as, according to that chemist, no change takes place in perfectly dry air; he ascertained that the acid increased in weight, though not more than a one hundred and sixtieth of the whole mass.

Various results have been arrived at by different chemists respecting the specific gravity of arsenious acid. The gravity of the opaque acid is, according to

Guibourt,	3·695
Taylor,	3·529
Brandt,	3·600

The gravity of the transparent acid is given by

Dumas,	3·698
Guibourt,	3·738
Brandt,	3·700

PEREIRA kept arsenious acid in a sealed tube for two years without any change being noticed, but on cracking the tube the transparency of the enclosed acid was, in a very short time, lost.

A singular property of arsenious acid observed by **ROSE** is, that when the vitreous acid is dissolved in hydrochloric acid, and allowed to cool slowly, vivid flashes of light are emitted from the crystals as they form. The phenomenon does not attend the crystallization if the opaque acid is dissolved in the acid liquor, neither will it succeed if the crystals deposited from the vitreous substance be redissolved in the acid, and suffered to cool as they acquire the property of the opaque acid; the production of the light seems to be connected with the transition from one modification to the other.

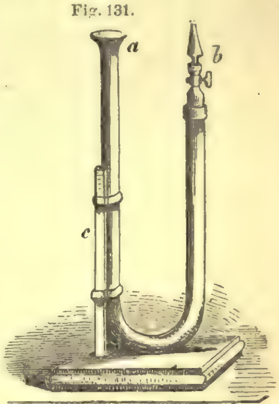
Heated on charcoal before the blowpipe, it emits the peculiar characteristic arsenical odor; when mixed with carbonate of soda and charcoal, and the compound subjected to heat in a glass tube, it yields a ring of metal which condenses on the cold part of the tube. Arsenious acid is decomposed at an incipient red heat by hydrogen, carbon, and many of the metals.

Sulphide of hydrogen produces, in solutions of arsenious acid, a lemon-yellow precipitate of tersulphide of arsenic, which is very characteristic of this body; the yellow tint being observed when a ten-thousandth of the acid is present, and a precipitate becoming visible in an acidulated solution of one part of arsenious acid in eighty thousand parts of water. Excess of lime-water occasions a white precipitate in a liquid containing about one five-hundredth of arsenious acid. Ammonio-sulphate of copper gives an apple-green precipitate in a solution of arsenious acid, thus indicating about a twelve-thousandth part of the acid; and according to **REINSCH**, when a slip of bright copper leaf is boiled in an aqueous solution, acidulated by hydrochloric acid, a grey film of arsenic is deposited upon the copper, showing the presence of less than a one hundred-thousandth part of the acid. Nitrate of silver gives with it a yellow precipitate.

The Editor considers the most infallible test to be the characteristic alliaceous odor which is evolved when this substance is heated before the blowpipe; he has several times astonished parties with the minute quantities of arsenic that could be detected, on submitting substances containing it to the action of reducing agents before the blowpipe flame.

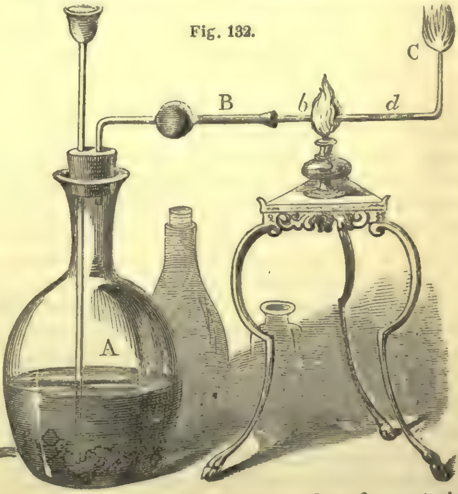
Arsenic forms a gas with hydrogen; the combination of the two elements may be effected by bringing together arsenious acid, or an arsenical compound, with zinc, water, and sulphuric or hydrochloric acid. This property was first taken advantage of as a test for the metal by the late Mr. **MARSH**, of Woolwich. The apparatus he employed is shown in an improved form in Fig. 131. The stopcock, *b*, being removed, a few fragments of depurated zinc are introduced into the bend, and pure dilute sulphuric acid poured upon them; the part, *b*, is fixed on, *a* is closed with the thumb, and the gas evolved having been proved to be free from arsenic, by no deposit being formed when burned against a porcelain plate, the suspected liquid is then examined in a similar manner.

Fig. 131.



Any apparatus, based on the same principle as the above, is called after **MARSH**. Fig. 132 is a convenient form. The materials for generating the hydrogen are introduced into the evolution flask, A, and the gas, discharged through a tube, B, filled with dry cotton-wool, is—sufficient time being allowed to expel the atmospheric air from the apparatus—inflamed at the point of the bent tube, C, and a porcelain plate depressed on the flame. If, after burning for some time, no incrustation or blackening appears on the plate, it is a sign that the materials are free from arsenic; additional assurance is, however, obtained by heating a portion of the horizontal tube to redness at *b*, by means of a spirit-lamp; no

Fig. 132.

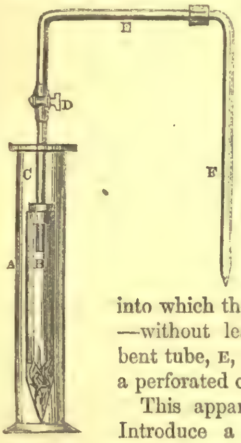


incrustation must be observed in the tubes. The liquid to be tested for arsenic is now introduced into the evolution flask through the funnel tube; and if it contain any traces of the poison, the flame of the hydrogen will acquire a bluish-white color, owing to the reduction and separation of the arsenic, and fumes of arsenious acid will make their appearance. On bringing the porcelain plate in contact with the flame, brown arsenic spots, having a shining metallic appearance, will be obtained.

On directing the flame of the spirit-lamp to the horizontal part of the tube, a beautiful incrustation of metallic arsenic, *d*, will be formed in the cold part; and on cutting off the end near the deposit, and applying heat, the arsenic is converted into arsenious acid, which may be dissolved in hot water, and tested by nitrate of silver and sulphate of copper.

The following—Fig. 133—is the modification of Marsh's apparatus, as given by Dr. Ure:—A is a narrow glass cylinder, open at the top, about ten inches high, and one inch and a half in diameter inside. B is a glass tube about one inch in diameter outside, drawn to a point at the bottom, and closed with a cork at the top. Through the centre of this cork, the small tube, C, passes down air-tight, and is furnished at the top with a stopcock, into which the small bent hard glass tube —without lead—E, is cemented. The bent tube, E, is joined to the end of F by a perforated cork.

Fig. 133.



This apparatus is used as follows:—Introduce a few oblong slips of zinc, free from arsenic, into B, and then insert its cork with the attached tubes. Having opened the stopcock, pour into the tube, A, as much of the suspected liquid, acidulated with dilute sulphuric acid, as will rise to the top of the cork after B is full, and immediately shut the stopcock. The generated hydrogen will force down the liquid out of the lower orifice of B into A, and raise it above the level of the cork. The extremity of the tube, F, being dipped beneath the surface of a weak solution of nitrate of silver, and a spirit flame being placed a little to the left of the letter E, the stopcock is then to be slightly opened, so that the gas which now fills the tube, B, may escape so slowly as to pass off in separate small bubbles through the silver solution. By this means the whole of the arsenic contained in the terhydride of arsenic will be deposited either in the metallic state upon the inside of the tube, E, or with the silver will pass into the characteristic black powder. The first charge of gas in B being expended, the stopcock is to be shut till the liquid is again expelled from it by a fresh disengagement of hydrogen.

The ring of metallic arsenic deposited beyond E may be chased onwards, by placing a second flame under it, which forms it into an oblong, brilliant, steel-like mirror. It is evident that, by the patient use of this apparatus, the whole arsenic in any poisonous liquid may be collected, weighed, and subjected to every kind of chemical verification. By means of the perforated cork, the tube, F, may readily be turned about, and its taper point raised into such a position as that, when the hydrogen issuing from it is kindled, the flame may be made to play upon a surface of glass or porcelain, in order to form the arsenical mirror.

Arsenious acid unites with most bases, with which it forms salts, called *arsenites.* With oxide of copper it gives compounds much used as pigments, and which will be hereafter described.

Arsenious acid is manufactured on the large scale only in a few establishments; it is, however, obtained as a secondary product in many metallurgic operations, such as those of cobalt, the ores employed containing a large proportion of arsenic. The principal places where the acid is prepared to a large extent are, Altenberg and Reichenstein, in Silesia, where the most improved methods are followed, as arsenious acid is the sole product of the manufacture. Arsenical iron, which is the ore employed, is coarsely ground, or broken up into small pieces, previous to its being introduced into the furnace, in which state it is called *schliech.* The roasting of the arsenical ore is somewhat similar to the manner of burning sulphur for the manufacture of sulphuric acid, but the fire is kept out of contact with the former, while it acts directly on the latter. In the succeeding figures, the kind of apparatus used is represented.

Figs. 134 and 135 are explanatory of the furnace: the first shows a longitudinal, and the second a transverse section; the same characters in each indicate the same parts. The muffle of the furnace, where the ore is deposited for roasting, is indicated by *a*; *b* is a door in the front of the muffle, through which the workman introduces his slicer to work the charge, and draw out the exhausted material; *c c c* are the flues round the muffle, where the smoke and flame from the fire are carried forward to the main flue, *e*, leading to the chimney. From the muffle, two channels, *f f*, lead to two others, *g*, and these terminate in a larger one, *h*, which opens into the first chamber, B, appropriated for the condensation of the acid. By the opening, *i*, the vapors of the acid uncondensed in B pass into the conduit, *k*, and thence by *l*—Fig. 136—into the lower of the compartments, *m n o p q r*, which compose the poison tower, where most of the gases evolved

Fig. 134.

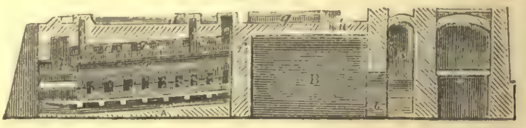
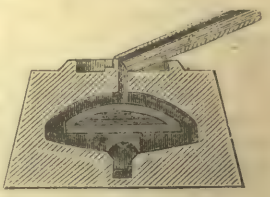


Fig. 135.



from the muffle are condensed. The sulphurous acid arising from the oxidation of a portion of the sulphur escapes through the top.

About ten hundredweight of the prepared ore—schliech—form the charge, which is introduced through the opening, *d*, and spread upon the inclined hearth of the furnace to the depth of from two to four inches. At first the application of the fire is well attended to, till the mass in the muffle approaches a red heat, after which it is abated to a certain degree, and maintained at that point till the whole of the charge is worked off, and this is effected in about twelve hours. The exhausted ore is now raked out at the front, and another charge introduced as before. During the roasting of the ore, the door, *b*, is kept open, that the air entering may oxidize the metals, and particularly the arsenic. The current of air is rendered more forcible in consequence of the heat in the furnace, and the declination of the hearth towards the front of the muffle. Frequent stirring of the metals is necessary to insure their complete oxidation.

Fig. 136.

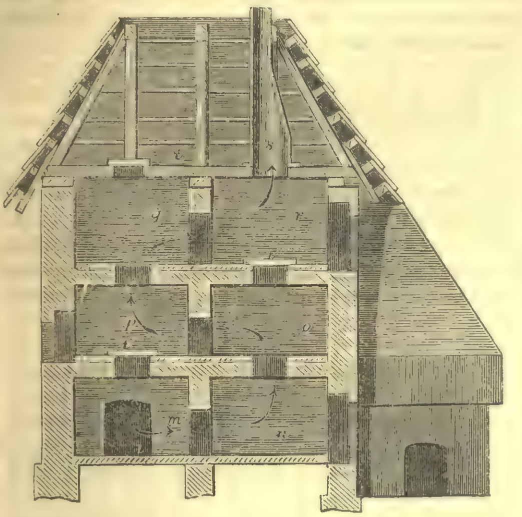


Fig. 136 is a section of the *poison tower*, where the arsenious acid is condensed in the spaces, *m n o p q r*; the fumes, as stated above, enter the lower compartment at *l*, and then follow the direction of the arrows, until, finally, the uncondensable vapors depart through the opening, *s*. In the flues and first chambers of the tower, the purest arsenic is to be found, that which is deposited in the upper ones being impregnated with sulphur. At the termination of the working of each charge, the covers, *t t t*, are taken away for the purpose of collecting the whole of the condensed arsenious acid into the lower chamber, which is emptied only about once in every two months, and contains at that period about twenty-five tons of the impure compound. At first sight a great deal of fuel would appear to be consumed; this, however, is not the case. The reason is, that the metals during the oxidation evolve so much heat, that only very little besides is required to maintain the equalized heat necessary to dispel the whole of the volatile products. About four and a half bushels of charcoal are sufficient to oxidize the quantity just mentioned.

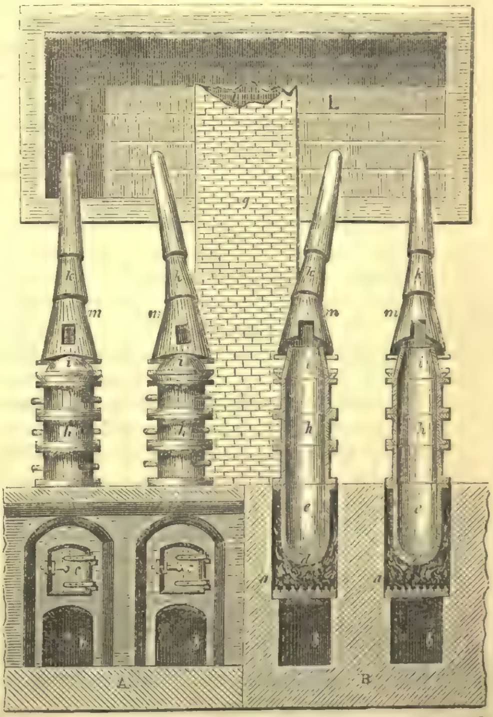
The arsenious acid procured by the foregoing mode is purified, before it is sent to market, by sublimation; the method, together with the representation of the furnace, adopted at Reichenstein for that purpose, are here given.

Fig. 137 is a drawing, which shows the front view of the furnace.

The part A is a front view of the half, and B a section of the other half. The fire-grates are indicated by *a a; b b* are the ash-pits, *c c* the doors, and *d d* the space appropriated for the fire to play under the bottom of the subliming pots; the smoke is carried off by the chimney, *g*. The subliming pots, *e e*, are made of cast-iron—or they may be of porcelain—and receive the crude arsenic to be sublimed; they are surmounted by iron drums, *h h*, serving as condensers, and are furnished with caps, *i i*, which in turn are covered with the funnelled pipe, *k k*, the narrow ends of which enter the condensing chamber, L. In these pipes, *m m* are openings to admit the insertion of a probing wire, to clear them when choked up by the sublimed material.

Each pot is charged with about three and a half hundredweight of the crude arsenious acid; the cylinders, *h h*, are then appended in their proper position by the aid of the handles with which they are supplied, and the joinings being well luted with a composition of loam, hair, and blood, the caps, *i i*, are adjusted, as also the pipes, *k k*, and lastly, the fire is lighted. A very gentle heat is applied for about half an hour, but this

Fig. 137.



may afterwards be raised to a higher degree, sufficient to conduct the operation without a too rapid effect. The arsenious acid by this means rises partly as a dusty white body, and partly assumes the crystalline shape; both forms, however, fuse by the further action of the heat, and give rise to a vitreous homogeneous mass. Only a sublimate of the acid is obtained when the heat is too feeble, and, on the other hand, much of the arsenic is driven into the pipes and condenser, if it rises beyond due limits. At the end of twelve hours the fire is allowed to go out, and when the furnace is cold, the cylinders are lifted off, and the glass of arsenious acid detached. Sometimes this glass is interspersed with dark spots of metallic arsenic; whenever this happens, either the whole compound must be sublimed anew, or those parts picked out, if such an operation is practicable. Good crude arsenious acid yields from three-fourths to seven-eighths of its weight of the purified substance.

Arsenious acid is used in considerable quantities for the purpose of destroying the color communicated by protoxide of iron in glass-making; in the preparation of various arsenical compounds, some of which are used extensively in printing; and by naturalists, to preserve organic specimens from putrefaction and the ravages of insects. In medicine, it is used only to a limited extent. It exerts a most destructive influence on the system.

ARSENIC ACID.—*Acide arsenique*, French; *arsensäure*, German; *acidum arsenicum*, Latin.—This acid was discovered by SCHEELE, who directed for its ready formation that arsenious acid should be dissolved in aqua regia—nitro-hydrochloric acid—and the mixture distilled to dryness in a retort, which leaves solid arsenic acid. The easiest method, however, of procuring this acid is, to dissolve arsenic in nitric acid, and to evaporate the solution to dryness. The taste of the acid thus prepared is not very remarkable when dry, but when moistened it becomes exceedingly acrid.

Arsenic acid is deliquescent and crystallizable; it fuses at an incipient red heat, concreting, on cooling, into a vitreous mass. At a higher temperature it is decomposed, oxygen is evolved, and arsenious acid sublimes. Its specific gravity is 3·7; six parts of cold and two parts of boiling water are required for its solution, which reddens vegetal blues, tastes acid and metallic, and is a more virulent poison than arsenious acid. It gives a white precipitate with lime-water, a peculiar reddish-brown with nitrate of silver, and gradually yields a yellow deposit of quinquisulphide of arsenic, when its solution is subjected to the action of a stream of sulphide of hydrogen gas. Its precipitate with ammonio-sulphate of copper is pale greenish blue. Arsenic acid consists of—

	Atomic weight.	Theory.	Berzelius.
1 Eq. of arsenic, ...	75	65·22	65·29
5 Eq. of oxygen, ...	40	34·78	34·71
1 Eq. of arsenic acid, ...	115	100·00	100·00

This acid gives salts with bases termed *arseniates*, but they have no commercial importance.

REALGAR.—RED ORPIMENT.—The artificial formation of this compound is not on an extended scale, as it is found in nature in considerable quantities; sometimes associated with native arsenic in veins and efflorescences, and, occasionally, crystalline in primitive mountains. It is most abundant in volcanic districts, as at Solfaterra, near Naples, and is, in some instances, sublimed in the shape of stalactites, as at the craters of Etna and Vesuvius. Natural specimens possess a very beautiful scarlet color, which, when powdered, is changed into an orange red; it is soft, and of a vitreous and conchoidal fracture.

Before the blowpipe it is volatilized, and evolves the peculiar arsenical odor, together with that of burning sulphur.

In the pure state it is composed of —

		Centesimally.	
	Atomic weight.	Found.	Theory.
1 Eq. of arsenic, ...	75	70·0	70·1
2 Eq. of sulphur, ...	32	30·0	29·9
	107	100·0	100·0

Realgar is made artificially, by distilling a mixture of arsenical iron pyrites, arsenious acid, and sulphur. For this purpose a furnace and gallery are erected, in which a number of earthenware retorts are placed, as seen in the annexed cuts—Figs. 138 and 139. The retorts are so disposed that they form two rows, and are composed of silica, iron filings, clay, and alumina, luted to the receivers, which are likewise of earthen or stoneware. A number of small holes permeate the receiver, to allow the gases which form during the distillation to pass off. In the course of the operation, the small holes become choked up from the deposit of sulphide of arsenic which forms on the interior of the vessel; and to prevent an explosion which the confined gases would occasion, the coating of realgar should be scraped off the upper part from time to time by a rod, which may be introduced in an opening for that purpose in the receiver. The retorts are charged to about two-thirds of their capacity with the prepared ore, and the necks adapted to the receivers; a very gentle heat is applied for an

Fig. 138.

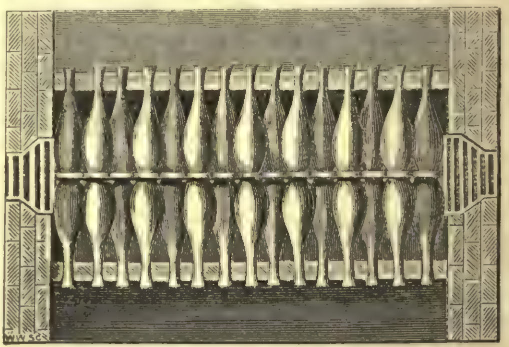
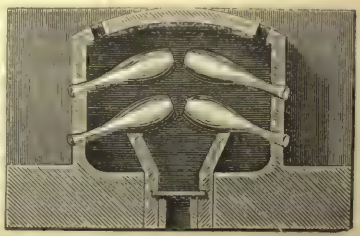


Fig 139.



hour and a half, or two hours, then gradually increased to redness, and maintained so for eight, ten, or twelve hours. During the distillation, the receivers are kept as cool as possible. On withdrawing them at the termination of the process, a yellow and red sulphide of arsenic, together with a red, vitreous, compact body, is obtained; the former is mixed with a fresh charge, and the latter purified for use. The operation is rather dangerous to execute, especially under a chimney having a strong draught. Cast-iron pots or cylinders are employed in the purification, and these are charged with from twenty-five to thirty pounds of the arsenical glass from the first preparation, and heat applied. The attendant ascertains if the proper shade of color is attained by introducing an iron rod into the fused mass; and on withdrawing it, he abstracts part of the compound. If the color be found too dark, some sulphur is added to make it lighter; and if too light, a quantity of a darker realgar is thrown in. When the operation is finished, the realgar is cast into sheet-iron cylinders and allowed to cool, after which it is packed for market. The residue left in the retorts after the first sublimation, consisting of sulphide of iron, *et cetera*, is employed sometimes in the manufacture of sulphate of iron or copperas.

ORPIMENT.—This is manufactured from the preceding compound of arsenic and sulphur, as also by fusing a mixture of arsenious acid and sulphur in refining kettles similar to those used for purifying arsenious acid. Some conflicting directions have been given for its preparation; as by fusing one part of sulphur with seven of arsenious acid. This might be taken as a misprint, were it not that GUIBOURT found, upon the analysis of such a sample, ninety-four per cent. of arsenious acid, and only six per cent. of orpiment.

To produce a good article, theory shows that four and a half equivalents of sulphur would be required to one equivalent of arsenious acid; or, numerically, eleven parts of the acid require eight of sulphur to combine with the arsenic and oxygen of the arsenious acid. Experience has proved that the more the manufacturer on the large scale works according to theory, the better and more economical will his trade become.

In making orpiment with realgar and sulphur, seven parts of the former should be taken to one of the latter, and the mixture fused as above. In the moist state, orpiment is prepared by precipitating a solution of arsenic in hydrochloric acid by sulphide of hydrogen, straining off the liquid, and drying the yellow precipitate. Orpiment has a bright yellow color, passing into orange when it is prepared by precipitation, but when obtained by fusion, it is more dark and crystalline after cooling; the fracture is conchoidal. Unlike the precipitated substance, the fused mass is slightly soluble in water, from which sulphide of hydrogen again throws it down as a yellow powder.

It is oxidized by nitric and nitro-hydrochloric acids, and dissolved by alkalies and alkaline carbonates—an arsenite of the base, with sulphide of the alkali metal, being formed, and carbonic acid expelled when the carbonate is used. Heated in close vessels, it fuses and sublimes; in air, sulphurous acid is evolved, and arsenious acid produced.

The composition of orpiment is

	Atomic weight.	Theory.	Berzelius.
1 Eq. of arsenic,..........	75	60·97	61·0
3 Eq. of sulphur,..........	48	39·03	39·0
	123	100·00	100·0

Formula, ...As S_3.

This compound of arsenic and sulphur, like the preceding, is still used, but to a limited extent, as a pigment in oil painting and lacquering. The two are occasionally employed to destroy the effect of the indigo, which is dissolved by the potassa used at the same time. Orpiment was once used to dye silks, by dissolving it in ammonia, and passing the weft through the solution thus produced. On hanging the cloth up in the stove-room, the volatile ammonia was expelled, and the color remained fixed upon the cloth. These compounds are highly poisonous, and should be used with the greatest care.

ARSENITES.—Arsenious acid unites with all the mineral bases, and forms with them definite compounds, which, however, are of little utility in a manufacturing or artistic sense, though, as the result of chemical research, they occupy a prominent position in scientific manuals. Those to which any interest is attached are, the *arsenite of potassa*, and the compounds known as *Scheele's green* and *Schweinfurth green*—the former an arsenite, and the latter an arsenite with a portion of acetate of copper.

Arsenite of Potassa.—This substance is formed by dissolving arsenious acid in a solution of caustic or carbonated alkali, and evaporating the solution; or, by decomposing arsenite of baryta by sulphate of potassa, double decomposition takes place:

$$\underbrace{\text{Ba O, As O}_3}_{\text{Arsenite of baryta.}} + \underbrace{\text{K O, S O}_3}_{\text{Sulphate of potassa.}} = \underbrace{\text{K O, As O}_3}_{\text{Arsenite of potassa.}} + \underbrace{\text{Ba O, S O}_3}_{\text{Sulphate of baryta.}}$$

It is the active ingredient in many patent medicines, such as *Fowler's mineral solution*, or *tasteless ague drop*, and is used for the preparation of other arsenites by double decomposition, particularly in the laboratory.

Scheele's Green.—This compound derives its name from SCHEELE, its discoverer, who gives the following direction for preparing it:—Dissolve two pounds of sulphate of copper in three gallons of warm water; in another vessel make a solution of two pounds of pure potassa, and eleven ounces of arsenious acid in one gallon of water; filter both through a cloth, and while warm, mix them portionwise, keeping the menstruum briskly agitated at each addition. As soon as the precipitate settles to the bottom, the clear liquid is to be decanted or siphoned off, and the green powder treated with a gallon or more of hot water, and agitated. Next it is to be thrown on a filter, again washed once or twice with water, and finally dried at a gentle heat.

Another process followed, is to dissolve two parts of sulphate of copper in forty-four of hot water, and to add to this solution another composed of two parts of carbonate of potassa, one of arsenious acid, and forty-four of water. The green powder which is thus produced is washed well with water, and dried at 212° Fahr.

Schweinfurth Green was first made in the year 1814, at the locality whence it takes its name. It is made by adding a solution of arsenious acid to verdigris. In the cold, the change produced is different from that which subsequently results; a precipitate forms, which, instead of being of the rich color of the compound, has an olive-green tint. This precipitate is, according to ERDMANN, arsenite of copper, and the solution contains the free acetic acid already in union with the base; on leaving the mixture for a long time to react, or by boiling it, a change occurs, and the olive-colored precipitate becomes of a beautiful brilliant green hue. BOOTH directs for its formation, ten parts of verdigris to be diffused through sufficient water to form a thin paste, and this passed through a sieve, after which eight or nine parts of finely-powdered arsenious acid are to be dissolved in a hundred of boiling water, and the solution added while at the point of ebullition to the infusion of the verdigris in water, in successive portions, taking care to stir the mixture well each time; and lastly, the whole is to be boiled for a few minutes, which is sufficient to develop the full tone of color. If cold water be poured into the hot solution without boiling, the peculiar green does not appear for some time; still, a more crystalline compound possessing a richer hue is in this way produced, than by the foregoing method.

BRANDT states another method, which is the following:—Fifty pounds of sulphate of copper and ten of lime are dissolved in twenty gallons of ordinary vinegar, and a boiling hot solution of fifty pounds of arsenious acid in water quickly stirred into it; the precipitate is dried and reduced to powder. In this, the precautions required in the preceding case will be applicable.

ERDMANN gives the annexed composition to the pigment:—

	Centesimally represented.
Arsenious acid,	58·622
Oxide of copper,	31·243
Acetic acid,	10·135
	100·000

Results which correspond with the formula—

$$Cu\,O, \bar{A} + 3\,(Cu\,O, As\,O_3).$$

It should be known that these compounds are highly poisonous, and therefore should be used with caution. It has been stated that these green pigments have been employed by confectioners to give color to their sweetmeats, a practice, if true, fraught with pernicious and fatal consequences.

QUANTITATIVE ESTIMATION.—Arsenic is quantitatively determined in various ways. The following is the method usually followed when no other compound but arsenic or its combinations is present.

In general cases, when the liquor contains other substances not precipitated by sulphide of hydrogen, the arsenical solution may be acidified with hydrochloric acid, and determined by passing through it a current of sulphide of hydrogen. If the liquor be dilute, a precipitate of sesquisulphide of arsenic is produced, the composition of which corresponds to that of arsenious acid. The stream of sulphide of hydrogen is continued until the liquor is completely saturated, the whole is then left at rest in a moderately warm place until the odor of sulphide of hydrogen has vanished, when the traces of sulphide of arsenic held in solution by the excess of the precipitant are thrown down. A small portion of the precipitate adheres so strongly to the side of the vessel, and of the glass tube which dips in the liquor, that it cannot be removed by mechanical means, but it is very easily dissolved by a few drops of ammonia; this solution is added to the acid liquor, which precipitates the small quantity of dissolved sulphide of arsenic. If the liquor contains any oxide of cobalt which is to be subsequently determined, a solution of carbonate of soda must be employed instead of ammonia, for the purpose of dissolving the small quantity of sulphide of arsenic just mentioned, because oxide of cobalt cannot be precipitated completely by potassa from a solution which contains ammonia.

The sulphide of arsenic obtained, is collected upon a tared filter, washed, dried at a very gentle heat, and then weighed. Were the operator quite sure that the solution contains arsenious acid only, he might calculate the quantity of this acid from that of the sulphide of arsenic produced, though even in that case the results would be erroneous, as the sulphide contains more sulphur than is found by calculation, being mixed with a little sulphur due to the decomposition of the excess of sulphide of hydrogen in the liquor. Whenever it is presumed that the solution contains a little arsenic acid, besides arsenious acid, the sulphide of arsenic obtained must be completely analysed, which, for the reason just stated, should always be done, even when the liquor contains arsenious acid only. The best method of performing this analysis is as follows:—

After having dried and weighed the sulphide of arsenic, all that can be shaken from the filter is put into a small matrass, or a large glass vessel, and the filter is again weighed in order to know the amount of substance submitted to experiment. Aqua regia is then poured upon it, and the whole left to digest for some time. The action of the acid upon sulphide of arsenic in fine powder is very energetic, even in the cold, owing to which the oxidation must be performed in capacious vessels. The arsenic is oxidized into arsenic acid, and a portion of the sulphur is converted into sulphuric acid, the remainder continuing in the pure state. In order to convert the whole of the sulphur into sulphuric acid, the digestion in aqua regia, which should be frequently renewed, would require too long a time. On this account, as soon as the sulphur is agglomerated into small lumps, it is collected upon a counterpoised dry filter, washed, dried most carefully, and weighed. A solution of chloride of barium is added to the filtered liquor, and the sulphate of baryta determined with the usual precautions; from its weight, that of the sulphur in solution is calculated. The sulphate of baryta is very difficult to wash, on account of the presence of nitric acid in the solution. The collective quantities of sulphur indicate that which existed in the sulphide of arsenic subjected to analysis; the loss indicates the loss of the arsenic, from which the proportion of the arsenious acid is calculated. It is necessary to take care in this operation, to collect the undissolved sulphur only after a prolonged digestion in aqua regia. The color of sulphide of arsenic does not differ much from that of sulphur, yet a little practice enables the operator to detect very readily whether the sulphur contains any of the metallic compounds.

Instead of the preceding, the following method may be adopted:—The acid liquor is supersaturated with ammonia, and a quantity of sulphide of ammonium is added thereto, which produces a precipitate of sulphide of arsenic, dissolving easily and completely in the excess of sulphide of ammonium, whether it be tersulphide or quinquisulphide of arsenic.

If the solution is very concentrated, it should be diluted with a large quantity of water, and hydrochloric acid carefully added, till it gives a feeble acid reaction with litmus paper. Sulphide of arsenic is thereby precipitated, with disengagement of sulphide of hydrogen. The liquor is digested at a gentle heat, until the odor of the sulphide of hydrogen has disappeared, and the sulphide of arsenic produced is separated by filtering.

Ordinarily, arsenic acid is precipitated by a solution of acetate or nitrate of lead, in the state of arseniate of lead, from the weight of which the quantity of the arsenic is determined; but this method is seldom satisfactory, and is attended with more difficulties than that just described, when the solution contains other metallic oxides.

It is absolutely necessary to analyse this sulphide, as before said, because it is mixed with much sulphur from the decomposition of the sulphide of ammonium. If the operator has not added a very large quantity of water to the solution of the sulphide of arsenic in sulphide of ammonium, before decomposing it by hydrochloric acid, and too large a proportion of this acid is subsequently added, the whole of the arsenic is not obtained in the state of sulphide. It is better, in a great number of cases, to decompose the liquor with acetic, instead of with hydrochloric acid. The sulphide of arsenic is much more completely precipitated by this than by the foregoing course of analysis.

It is also necessary to determine the quantity of the arsenic acid in the arseniate of lead produced, in order to obtain anything like tolerable accuracy; this procedure is much more complicated than the quantitative determination of arsenic in the state of sulphide.

Arsenic is separated from lead, mercury, silver, bismuth, cadmium, and copper, by digesting the mixed sulphides in an excess of sulphide of ammonium, which dissolves the sulphide of arsenic. The solution is subsequently filtered off, and the sulphide of arsenic thrown down from the filtrate by addition of a slight excess of hydrochloric acid; and on the deposited sulphide being refiltered, washed, dried, and treated as in the foregoing process, the amount of arsenic is found. Antimony and tin are most difficult of separation from this metal.

ROSE recommends the following for separating antimony from arsenic:—The alloy is heated to redness in an atmosphere of hydrogen gas, in an apparatus similar to Fig. 128, represented at page 211. When the quantity of arsenic is considerable, it is necessary that the diameter of the tube, soldered to the further side of the glass bulb containing the alloy, be not too small.

As soon as the apparatus is filled with hydrogen gas, heat is applied to the bulb, and is continued until no more metallic arsenic is deposited in the end tube. By means of a small spirit-lamp, the metal is constantly expelled from the tube, leaving it clear.

When the arsenic has been completely eliminated from the tube, the glass bulb is suffered to cool, but without interrupting the current of hydrogen. It is then weighed with the residuum of metallic antimony, and the loss indicates the quantity of arsenic. It is necessary in this operation not to employ too strong a heat, which would slightly volatilize the antimony. It is scarcely necessary to add, that the operator should take great care not to inhale the arsenical vapors, on which account the experiment must not be conducted in the laboratory, but under the hood of the furnace opening into the chimney-flue. Nearly all the arsenic found in nature, under the name of *native arsenic*, contains small quantities of antimony, which may be determined by the previous method.

When, however, antimony and arsenic exist in solution, or when the two metals being combined in the solid state are united with other substances, so that the method which has just been described cannot be employed, another process must be adopted to separate them from each other. The solution is diluted with a sufficient quantity of water, after having added tartaric acid thereto, without which precaution the addition of water would render it milky.

If the combination under examination consists of metals in the reguline state, it is dissolved in aqua regia, tartaric acid is poured into the solution, and water is then added. A current of sulphide of hydrogen is next passed through the liquor to saturation; it is then very gently heated, in order that the metallic sulphide may settle completely. When the solution contains arsenic acid, it may be easily perceived that the first precipitate formed is sulphide of antimony, and it is only after some time that the sulphide of arsenic falls down, so that at first a layer of an orange-red color is deposited, which is covered afterwards by another layer of a light, yellow color. It is therefore necessary, before filtering, to mix these two layers well together by stirring with a glass rod. The whole is then filtered through a weighed filter, upon which the sulphides are dried at an extremely gentle heat until their weight remains constant. After having determined the weight of these sulphides, a portion—about half of it—is shaken down into a glass, the remainder is very gently heated again with the filter, and the whole is weighed for the purpose of ascertaining the weight of the portion about to be operated upon. The portion in the glass is to be treated very cautiously with aqua regia till the sulphides are oxidized.

Tartaric acid is then added to the solution, which is to be diluted with water. If any sulphur has separated, it must be filtered from the liquor, and its quantity ascertained. Chloride of barium is now poured into the filtrate, to precipitate the sulphuric acid which has been formed. From the weight of sulphate of baryta, that of the sulphur which it contains is calculated, and the portion of sulphur which has not been oxidized by the aqua regia is added to the quantity previously determined. The whole of the sulphur contained in a given weight of metallic sulphide having thus been determined, it is easy to deduce therefrom the collective weight of the antimony and arsenic.

The quantity of antimony is determined in another portion of the mixed sulphides, in the same manner as directed for that metal in the preceding page. When the amount of antimony and sulphur are known, the arsenic is easily found by deducting the united weights of those two bodies from the quantity of the mixed sulphides taken; the difference is the weight of the arsenic.

Levol estimates the arsenic which may be alloyed with copper and tin in bronzes, as follows:—Having dissolved the compound in hydrochloric acid and evaporated to dryness, nitric acid is added, and the whole heated, which renders the tin, in the form of binoxide or stannic acid, insoluble, and the arsenious acid partially remains with it. The precipitate is dried and reduced by hydrogen gas. The reduction takes place at a dull red heat, the greater part of the arsenic being separated by sublimation; a small quantity still remains with the tin, but this is removed by treating the alloy with hydrochloric acid, which dissolves the tin, leaving the other constituent undissolved. The compound may also be acted upon by zinc and sulphuric or hydrochloric acid, by which treatment the whole of the arsenic is removed in the form of gaseous terhydride, from which the metal may be abstracted, and its quantity estimated by transmitting the gas through a solution of protoxide of tin, of known strength, at a slightly elevated temperature—the arsenic is taken up by the tin, and may be found by the increase of the weight of the latter. A solution of tin in cold weak nitric acid, appeared to **Levol** to be the most effectual for collecting the arsenic; the soluble protosalt thus formed readily comes in contact with the molecules of the arsenic, and when the temperature of the liquid is raised to convert the protoxide of tin into peroxide, the latter seizes on the arsenic and carries it down as it precipitates.

If arsenious and arsenic acids are present, they may be thus determined. The solution of the two acids is divided into equal parts; one part is treated with a stream of sulphide of hydrogen, and the second portion reserved for further operations. The sulphide of arsenic which falls is collected, dried at 212° Fahr., and weighed, after which the amount of sulphur is determined as before specified.

A solution of indigo, together with a quantity of hydrochloric acid, is poured into the second portion; a weighed quantity of hypochlorite of lime is next taken, and dissolved in a definite measure of tepid distilled water, and the solution subsequently dropped from a burette into the arsenical colored liquid, till the blue of the indigo disappears. By knowing the weight or volume, together with the strength, of the liquid employed, the chlorine required to effect the oxidation of the arsenious acid is calculated. The principle of the decomposition of the hypochlorite of lime by the hydrochloric acid, is the annexed:—

$$\underbrace{\mathrm{Ca}\left\{\begin{matrix}\mathrm{Cl}\\ \mathrm{O}\end{matrix}\right\}}_{\text{Hypochlorite of lime.}} + \underbrace{\mathrm{H\,Cl}}_{\text{Hydrochloric acid.}} = \underbrace{\mathrm{Cl}}_{\text{Chlorine.}} + \underbrace{\mathrm{Ca\,Cl} + \mathrm{H\,O}}_{\text{Chloride of calcium and water.}}$$

Or,

$$\underbrace{\mathrm{Ca\,Cl, Ca\,O, Cl\,O}}_{\text{Hypochlorite of lime.}} + \underbrace{\mathrm{2\,H\,Cl}}_{\text{Hydrochloric acid.}} = \underbrace{\mathrm{2\,Ca\,Cl}}_{\text{Chloride of calcium.}} + \underbrace{\mathrm{2\,H\,O}}_{\text{Water.}} + \underbrace{\mathrm{2\,Cl}}_{\text{Chlorine.}}$$

And the oxidation of the arsenious acid by the liberated chlorine is shown in the following equation:—

$$\underbrace{\mathrm{As\,O_3}}_{\text{Arsenious acid.}} + \underbrace{\mathrm{2\,Cl}}_{\text{Chlorine.}} + \underbrace{\mathrm{2\,H\,O}}_{\text{Water.}} = \underbrace{\mathrm{As\,O_5}}_{\text{Arsenic acid.}} + \underbrace{\mathrm{2\,H\,Cl}}_{\text{Hydrochloric acid.}}$$

On calculating the quantity of arsenious acid found, and deducting it from the total weight of arsenic indirectly ascertained by the foregoing analysis, the difference in weight is the arsenic present in the form of arsenic acid.

BALSAMS.—*Baumes*, French; *balsame*, German.—This term was formerly applied to all liquid vegetal resins, as well as to a great number of pharmaceutical preparations. To avoid confusion, the French chemists confine the term balsam to vegetal substances composed of benzoic acid with more or less volatile oil. But as this would exclude copaiba and some other substances, popularly called balsams, most of the German chemists retain the old acceptation, and divide balsams into those which do not, and those which do, contain that acid. To the former, which are also called oleo-resins, liquid resins, terebinthinates, belong the different turpentines, including Canada balsam, copaiba, and opobalsamum, or Mecca balsam: they are semi-liquid, resinous, or glutinous juices, which flow spontaneously, or by incisions, from various vegetals, especially those belonging to the orders Coniferæ, Terebinthaceæ, and Leguminosæ. They have a hot and acrid taste, and a strong odor, which, in some, is very fragrant, in others less agreeable, but peculiar. They consist of a volatile oil and resin. Their odor. their semi-liquidity, and most of their medicinal activity, are owing to the oil which they contain; this may be procured from them by distillation, and volatilizes by exposure to air, whereby they become hard. From the next, or true balsams, they may be readily distinguished by not yielding benzoic acid. Those balsams which contain benzoic acid, or balsams properly so called, are solid, soft, or liquid substances, according to the quantity of volatile oil in their composition; they have an aromatic, usually agreeable odor, and a warm acrid taste. They dissolve in alcohol, and the solution, when mixed with water, becomes milky, owing to the precipitation of resin. By sublimation, as well as by other methods, they afford benzoic acid, from which they derive their physical effects. They are procured chiefly from the orders Styraceæ, Leguminosæ, and Balsamaceæ. To this class belong benzoin, styrax or storax, Tolu and Peru balsam, dragon's-blood, and liquidambar.

The class of bodies comprehended under the general name of balsams, has not been forgotten in that active investigation of organic bodies to which several chemists have, with peculiar predilection, devoted themselves, especially since the discovery of easier and more certain methods of research, than those formerly known, have removed the chief difficulties.

A strict examination of the substances has been necessary, as the knowledge of them given in scientific works did not correspond with the advanced state of chemistry. In former times, the analyses of the balsams were purely qualitative; everything crystalline, and which united with a base, was considered as benzoic acid; those which did not enter into union were described as camphor. If, on distillation, a volatile fluid passed over, it was deemed sufficient to state that the substance contained also a volatile oil. In the present advanced state of analysis, greater precision is required, and every constituent of a compound is submitted to careful investigation.

CANADA BALSAM.—This is a turpentine from the balm of Gilead fir—*abies balsamea.* It is slightly yellow, transparent, possesses an agreeable terebinthic odor, and an acrid taste. When fresh, it flows readily, but in time solidifies. BONASTRE analysed this balsam, and found the following:—

	Centesimally represented.
Essential oil,	18·600
Resin, soluble in alcohol,	40·000
Resin, difficultly soluble,	33·400
Elastic resin,	4·000
Bitter extractive and salts,	4·000
	100·000

COPAIBA BALSAM is obtained from incisions made in the trunk of the *Copaifera officinalis,* a tree which grows in the Brazils and Cayenne. It is of a light yellow color, rather liquid, transparent; has a bitter, sharp, burning taste, a suffocating and unpleasant smell; specific gravity 0·950 to 0·996; soluble in absolute alcohol, partially dissolved by spirit of wine, and gives, with alkalies, crystalline compounds. It dissolves with the aid of a gentle heat one-fourth its weight of carbonate of magnesia, and remains translucent. The analysis yields the annexed:—

	Centesimally represented.
Volatile oil,	38·00
Copaivic acid,	52·75
Brown soft resin,	1·66
Water and loss,	7·59
	100·00

The oil contains no oxygen, has a composition like oil of turpentine, and, according to DURAND, dissolves caoutchouc.

Copaiba balsam is used for making paper transparent, for certain lacquers, and in medicine. In the latter, PEREIRA preferred the oil to any preparation of the balsam. SIMON remarks that the genuineness of copaiba balsam is frequently tested by mixing three parts of it with one part of ammonia, specific gravity 0·96; if the mixture be rendered clear by agitation, the balsam is usually considered genuine; but if to this balsam the sixth part of oil of juniper be added, it behaves with ammonia precisely as if none of the juniper oil were present, which proves the insufficiency of the above test. The same chemist further adds:—Of late there has frequently appeared in commerce, a balsam which will not at all bear the above test with ammonia; much trouble has been taken to detect any adulteration in this, but it is perfectly genuine. It contains from twenty to twenty-five per cent. more essential oil, which renders it more liquid, but the oils from both kinds of balsam are identical in odor, and in all other properties; the residuous resin in both kinds becomes equally hard and brittle, which entirely does away with the supposition of its having been sophisticated with any fat oil: the two resins, however, differ; the one affording a soapy combination with caustic alkalies, which the resin of the new balsam does not.

The different sorts of balsam of copaiba hitherto found in commerce, are characterized by the presence of an acid—copaivic acid—in consequence of which, if mixed in proper proportions with solutions of potassa or ammonia, they form therewith a more or less clear liquid, crystals of ammoniacal salt precipitating from the latter after some time. Hitherto, if this reaction did not take place, the balsam has been supposed to be adulterated with fixed oils, turpentine, *et cetera.*

Recently, however, as just observed, a balsam has been introduced into commerce which does not show this reaction, and is, notwithstanding, unadulterated. This kind was imported into London by one of the most respectable firms there, and was accompanied with the assurance that the article was not sophisticated, and came originally from the Brazils. The statement was supported by analysis, and the conclusion to be drawn therefrom is, that some species of Copaifera, or some allied genus, yields a balsam, greatly resembling the ordinary balsam of copaiba, and yet essentially differing from it in its nature.

The balsam in question is thinner, and of a lighter yellow color than the common kind, so that it is strikingly distinguished from the latter by this character. It possesses the disagreeable smell of the balsam of copaiba, and the peculiar persistent taste, in perfect purity. The specific gravity is 0·94. Mixed with solutions of potassa or ammonia, it remains in all proportions turbid, and never forms a saponaceous mixture with them; after some time it again separates from these liquids. In alcohol it does not perfectly dissolve, like the ordinary copaiba balsam, but forms with it a milky liquid. This originates from a resin contained in it, which does not dissolve in alcohol. It contains eighty-two per cent. of oil, and eighteen per cent. of resin.

In order to obtain the volatile oil in a pure state, the balsam was distilled with the addition of water. By this process, one part of oil and about thirty-two parts of water were obtained. The distilled oil was subjected to distillation with a fresh addition of water, and the oil thus procured, which was clear, was dried by chloride of calcium. It is thick, colorless, has a strong and pure copaiba smell, and an acrid, burning taste. Its specific gravity is 0·91; the boiling point is at 485° Fahr. The boiling oil readily becomes decomposed by the heat: it assumes a yellowish color, becomes viscid, then brown, thick, and glutinous, and at last is perfectly decomposed, whilst carbon is separated; hence the specific gravity of the vapor could not be determined. With ether it can be mixed in all proportions, but not so with absolute alcohol, of which a rather large quantity is required for its complete solution. In common alcohol it dissolves with great difficulty; if dry ammoniacal gas be passed into it, it rapidly absorbs it, and enters into combination, forming a reddish-brown fluid, which, if saturated, fumes in the air. Neither by leaving it at rest, nor by cooling it, could a crystallizable compound be obtained from this solution.

According to an analysis of this oil, it belongs to the carbide of hydrogen oils, being free from oxygen, and is composed after the general formula, $C_{10} H_8$. It is distinguished from ordinary oil of copaiba by its viscidity, by its behavior with alcohol and ammoniacal gas, and by its boiling point, and resembles it only in smell. It may be denominated *Paracopaiba oil.* Nitric acid, of 1·32 specific gravity, produces no reaction at common temperatures. If, however, it be heated, a violent reaction takes place, and the oil is converted into a resinous substance. If diluted nitric acid be employed, the mixture boils quietly, without coming over, and within a few days the oil dissolves perfectly in the liquid. At the same time, nitrous acid, carbonic acid, and volatile peculiar acids, are eliminated, which form, with acetate of lead, a precipitate, but which have not been further examined. The residue being evaporated, and diluted with water, yields an acid resin not affected by nitric acid, and a crystallizable acid, which remains in solution, whilst the former is precipitated. This resin is of a yellowish-red color, dissolves in some degree in boiling water, and forms again a milky precipitate when cold. In ether and alcohol it dissolves with facility, and from the spiritous solution small resinous crystals are afterwards precipitated. It has a strong acid reaction, and forms, with potassa or ammonia, red neutral compounds, which are soluble in water.

The acid which is obtained after the evaporated nitric acid solution of the oil has been freed from the resin just described, by the admixture of water, crystallizes in thin, transparent, colorless laminæ. It dissolves easily in water, spirit of wine, ether, and petroleum, is inodorous and bitter, and has a slight acid reaction. Although a great quantity of volatile oil had been employed, only a small quantity of acid was obtained, which was not sufficient for further experiments.

Fuming nitric acid detonates with the paracopaiba oil without the application of heat; iodine, however, is dissolved by it, without effecting any brisk reaction. Chlorine produces a violent disturbance, hydrochloric acid vapor escapes, and the mass becomes yellow and viscid; strong sulphuric acid induces a deep violet color.

The difference between the resins of the two sorts of balsam of copaiba is still greater than that between the volatile oils.

In order to obtain the resins in a pure state, the balsams—freed by distillation with water from the greater part of the volatile oil—were further boiled with water, till at last every trace of smell had disappeared. A light-brown brittle substance remained, which consisted of two distinct resins, but both absolutely indifferent. They can easily be separated from one another by alcohol, in which one dissolves with great facility, whilst the other is scarcely soluble, even when the alcohol is absolute and hot.

The resin soluble in alcohol constitutes the greater proportion, and can be obtained in a pure state by repeated solution in this menstruum; the other resin wholly remains behind. The former is of a light-yellow color, not friable in the cold, softens at a gentle heat, and is decomposed if the temperature be slightly increased; at the same time it assumes a deeper color, and becomes a viscid fluid. In weak boiling spirit it dissolves, but precipitates again for the most part in the cold, in the form of white flakes. In concentrated alcohol it readily dissolves also in the cold; equally so in ether and petroleum. The alcoholic solution has no acid reaction, and if left at rest the resin precipitates, in proportion as the alcohol evaporates, in small drops which betray no trace of a crystalline texture. With acetate of copper no precipitate is formed; in solutions of potassa or ammonia it does not dissolve.

Two analyses gave the annexed results:—

	Centesimally represented.	
Carbon,	59·98	60·06
Hydrogen,	8·48	8·27
Oxygen,	31·54	31·67
	100·00	100·00

The resin insoluble in alcohol remains after the preparation of the first. It should be boiled again several times in absolute alcohol, in order to obtain it perfectly pure. During this process its quantity considerably diminishes; it is then to be dissolved in ether, and the solution filtered and heated for some time on the water-bath, in order to expel the last traces of solvent.

It possesses the same color as the first, does not dissolve in dilute alcohol, is soluble only with difficulty in boiling absolute alcohol, and when cold, again precipitates for the most part from this solution. In ether and petroleum it readily dissolves. The solution has not an acid reaction, and no crystals could be obtained from it. In a solution of potassa or ammonia it is perfectly insoluble; if boiled with it, it forms a milky turbid mixture; the resin, however, precipitates again, perfectly, when at rest. With acetate of copper, a slight precipitate is formed. It melts with difficulty.

The elementary analyses of two samples prepared in different ways, gave the following:—

	Composition per cent.	
Carbon,	81·76	82·12
Hydrogen,	10·56	10·48
Oxygen,	7·68	7·40
	100·00	100·00

The analyses were performed with oxide of copper and chlorate of potassa, for without the addition of the latter no perfect combustion could be effected.

OPOBALSAM.—BALM OF GILEAD—MECCA BALSAM.—This is a whitish, turbid liquid, flowing from incisions made in the *Balsamodendron Opobalsamum*, or Beshan of Arabia. It is very odorous, and on exposure resinifies. The analysis gives

	Centesimally.
Volatile oil,	30·00
Soft resin, insoluble in alcohol,	4·00
Hard resin, soluble in alcohol,	64·00
Extractive,	0·40
Loss,	1·60
	100·00

Its physiological effects are believed to be similar to those of balsam of copaiba and the liquid turpentines.

It is never employed by Europeans, but the Asiatics use it for its odoriferous as well as its medicinal qualities, and they have ascribed to it the most wonderful properties.

BENZOIN, OR GUM BENJAMIN.—*Benzoin*, French; *Benzöe*, German.—Benzoin is improperly called a gum, as it ranks among balsams. It is a species of resin, and is used chiefly in perfumery. It is extracted by incision from the trunk and branches of the *Styrax benzoin*, or *Lithocarpus benzoin*, which grows in Java, Sumatra, and in the kingdom of Siam. The plant belongs to the Decandria monogynia of LINNÆUS, and the natural family of the Ebenaceæ. The bark of the six year old tree is slit to allow a liquid to flow out, which concretes by exposure to the sun and air, and is imported in brittle masses, the fracture of which presents a mixture of red, brown, and white grains of various sizes; when white, and of a certain shape, they are called *amygdaloid*, from their resemblance to almonds. The *sorted* benzoin is, on the other hand, very impure.

Its fracture is conchoidal, and its lustre greasy: its specific gravity varies from 1·063 to 1·092. The smell is agreeable, somewhat like vanilla, which is most manifest when it is ground. It enters into fusion at a gentle heat, and then exhales a white smoke, which may be condensed into the acicular crystals of benzoic acid, of which it contains eighteen parts in the hundred. The following is a good process for extracting the acid: The resin is to be dissolved in three parts of alcohol, the menstruum introduced into a retort, and a solution of carbonate of soda dissolved in dilute alcohol gradually added to it, till the free acid be neutralised; then a bulk of water, equal to double the weight of the benzoin, is to be poured in. The alcohol being drawn off by distillation, the remaining liquor contains the acid, and the resin floating upon it may be skimmed off and washed, when its weight will be found to amount to about eighty per cent. of the raw material. The benzoin contains traces of a volatile oil, and a substance soluble in water, at least through the agency of carbonate of potassa. Ether does not dissolve benzoin completely. The fat and volatile oils dissolve very little.

The benzoin of Siam, which has been recently introduced into commerce, consists of agglutinated, broad, laminar pieces, and does not essentially differ from the preceding. From some experiments which WACKENRODER has made with it, five per cent. of benzoic acid might be extracted from it by treatment with carbonate of soda; and the residue afforded, on being boiled with hydrate of lime and much water, four per cent. more of pure benzoic acid. There is, therefore, a difference between this benzoin and the other kinds previously known, in the amount of acid.

The several sorts of benzoin met with may be conveniently arranged under two heads, *videlicet*—*Siam benzoin* and *Sumatra benzoin*. PEREIRA states that Siam benzoin is brought to England, either direct from Siam, or indirectly, by way of Singapore. It includes the best commercial sorts, or those known commercially as benzoin of the finest quality. It occurs in tears, in irregular lumps, and in cubical blocks; but, unlike the Sumatra, it never comes over enveloped in calico. It is in general distinguished from the other kinds by its warmer or richer tints. The dealers distinguish five or six qualities, the three best sorts being included under the name of *yellow Siam benzoin*, and the two or three inferior kinds being called *red* or *brown Siam benzoin*. The designations yellow, red, or brown, are used according to the tint of the resin by which the tears are agglutinated; but this division is altogether arbitrary, the colors passing indefinitely into one another.

SIAM BENZOIN IN TEARS.—*Benzoinum Siamense in lachrymis*, Latin; *yellow benzoin in the tear*.—This kind seems to be identical with the *true benzoin in tears*, which SAVARY says was brought in considerable quantity to Paris by the attendants of the Siamese ambassadors. It consists of irregular flattened pieces, some of which are angular, and the largest of them barely exceeding an inch in length. Externally, these pieces are shiny or dusty from their mutual friction, and are of an amber or reddish-yellow color; they are brittle, and may be easily rubbed to powder. Internally, they are translucent or milky, and frequently striped; they have a pleasant odor, but little or no taste. There is an inferior sort in tears, which consists of loose drops, mixed with pieces of wood and other impurities. It is worth only one-fourth of the price of clean good-sized tears, or clean lump.

SIAM OR LUMP BENZOIN.—*Benzoinum Siamense in massis*, Latin.—The finest kind consists of agglutinated tears, *white or yellow lump benzoin*. More commonly the tears are connected together by a brown resiniform mass, which, when broken, presents an amygdaloid appearance, from the white tears embedded in the mass—*amygdaloid benzoin*.

Inferior sorts of lump benzoin are reddish—*red lump benzoin*.

TRANSLUCENT BENZOIN.—Dr. ROYLE furnished Dr. PEREIRA with a sample of Siam benzoin, with properties somewhat different from the preceding. The small masses consisted of agglomerated tears, which, instead of being white and opaque, were translucent, or, in a few instances, almost transparent.

SUMATRA BENZOIN.—*Benzoinum ex Sumatra*, Latin. Though placed here second, this sort is the more important, being in many countries the only kind known. It is rarely imported directly from Sumatra, but, in general, indirectly by way of Singapore or Bombay, and now and then from Calcutta. Hence it is sometimes called Calcutta benzoin, though this port is out of the usual course.

It occurs in large rectangular blocks, marked with the impression of a mat, and covered with white cotton cloth. When broken, but few large white tears can be observed in it. The mass is principally made up of a brown resiniform matter, with numerous white small pieces of chips intermixed, which give to the broken surface a speckled appearance, like that of a fine-grained granite.

WACKENRODER obtained nine per cent. of benzoic acid from the benzoin of Siam.

The qualities of Sumatra benzoin are distinguished as *firsts*, *seconds*, and *thirds*.

The first sort occurs very seldom, and only by single chests, for which £50 or more the hundredweight are paid, for the Russian market.

The second sort is marbly, but not so white; and is also mostly taken for the Russian market, at £20 to £30 the hundredweight. Thirty chests of this sort, perhaps, are seen before one of the first quality is met with.

The third sort is browner, and less or not at all marbly. It fetches from £9 to £15 per hundredweight, and forms the usual commercial quality. Five times as much of this are met with as of all the other sorts put together.

There is a very inferior sort of benzoin—*inferior Bombay benzoin*—which invariably comes by way of Bombay. If it be the produce of Sumatra, it is remarkable that it never comes by way of Singapore.

Benzoin is sometimes imported into England direct from Siam and Sumatra; but usually indirectly from Singapore, Bombay, Penang, Calcutta, Madras, Batavia, *et cetera.* The greater part is re-exported for use in the ceremonies of the Greek and Catholic Churches. In 1839 only one hundred and eight hundredweight paid duty.

This balsam has repeatedly been the subject of chemical analysis. It was analyzed in 1811 by BUCHOLZ, in 1816 by JOHN, in 1823 by STOLTZE, and in 1845 by KOPP. It has also been examined by BRANDE, UNVERDORBEN, and others:—

	Bucholz.	John.	Stoltze.		
			White.	Amygdaloid.	Brown.
Volatile oil, aroma,	—	—	traces	traces	traces
Benzoic acid,	12·5	12·0	19·80	19·42	19·70
Resin { yellow, soluble in ether,	83·3	84·5	79·83	27·10	8·80
Resin { brown, insoluble in ether,			0·25	50·53	69·73
Matter like balsam of Peru,	1·7	—	—	—	—
Aromatic extract,	0·5	0·50	—	0·25	0·15
Ligneous matter and other impurities,	2·0	2·00	—	2·60	1·45
Water and loss,	—	0 25	0·12	0·10	0·17
Salts, benzoates, and phosphates,	—	0·75	—	—	—
Benzoin,	100·0	100·00	100·00	100·00	100·00

Benzoin, in its physiological effects, is similar to the other balsams; it is therefore used with advantage in chronic pulmonary catarrhs.

UNVERDORBEN found in benzoin, besides benzoic acid, no less than three different kinds of resin; none of which has, however, been turned to any use in the arts Annexed are his results·—

	Centesimally represented.	
Benzoic acid,	14·5	14·0
Resin, soluble in ether,	48·0	52·0
Resin, soluble in alcohol only,	28·0	25·0
Resin, soluble in carbonate of soda,	3·5	3·0
Brown resin, deposited by ether,	0·5	0·8
Impurities,	5·5	5·2
	100·0	100·0

According to KOPP'S researches, benzoin resin, subjected to distillation, is resolved into carbon, carbide of hydrogen, water, carbolic and benzoic acids. Thus, four equivalents of the resin—$C_{20} H_{11} O_4 = C_{80} H_{44} O_{16}$—produce—

3 Eqs. benzoic acid,	C_{42}	H_{18}	O_{12}
1 Eq. carbolic acid,	C_{12}	H_6	O_2
8 Eqs. carbon,	C_8		
2 Eqs. water,		H_2	O_2
18 Eqs. olefiant gas,	C_{18}	H_{18}	
	C_{80}	H_{44}	O_{16}

Benzoin is of great use in perfumery, as it enters into a number of preparations; among which may be mentioned fumigating pastilles and cloves, *poudre à la maréchale, et cetera.* The alcoholic tincture, mixed with water, forms *virginal* milk. It enters also into the composition of certain varnishes employed for snuff-boxes and walking-sticks, to give these articles an agreeable smell when they become heated in the hand. It is likewise added to the spiritous solution of isinglass, with which the best court-plaster is made.

The chief use of benzoin is in yielding benzoic acid; it forms a component of the incense burned during the ceremonies of the Roman Catholic Church, and contributes to the peculiar fragrancy of the perfume.

When the balsam is of the *best* quality, its fracture has the appearance of white marble; but this kind is seldom encountered. The value of this article may be judged of by the amount of benzoic acid it yields; when good, it ought to give fifteen or eighteen per cent.

STORAX BALSAM belongs to the same natural family as benzoin, being the product of *Styrax officinalis*, a handsome shrub, growing in the Levant, Palestine, Syria, and Greece, and cultivated in the Southern parts of Europe. The storax of commerce comes from Asiatic Turkey. The balsam exudes from incisions through the bark; and, when somewhat hardened, constitutes one or more of the balsamic substances known by druggists under the name of storax. The bodies thus denominated are very numerous, and of variable character and composition; they are for the most part artificial compounds, perfectly dissimilar from any of the genuine varieties. Real storax is extremely rare. It occurs, says BRANDE, in compact masses, of a very fragrant odor, and of a rich brown color, interspersed with white tears, whence the name *amygdaloid styrax.* It was formerly imported enveloped in a monocotyledonous leaf, under the name of cane or reed styrax—*styrax calamita.* In the drug market, two substances are generally met with bearing the name of storax; one of them is called *styrax liquidus;* it is usually of a black, brown, or grey color, and generally has a disagreeable odor, more resembling that of coal-tar than of the balsam. The other is usually labelled *styrax calamita*, and is a black, brown, or purplish article, either pulverulent or granular, or in the form of agglutinated lumps. Some of it is said to consist of pulverized decayed wood, imbued with a little liquid storax; other samples appear to be fine sawdust, impregnated either with coal-tar or something analogous, and not bearing the remotest similarity to the genuine balsam.

Simon first showed that the acid found in storax, and which had always been taken for benzoic acid, possessed all the properties of cinnamic acid; and an analysis of the silver salt by **Marchand** proved the acid to be the latter. Storax, as well as the tree producing it, was known to the ancient Greeks and Romans. It is alluded to by **Hippocrates**, **Theophrastus**, and **Pliny**.

Pereira states that he has met with two kinds of liquid storax in the shops; one is opaque, and the other pellucid. He thus describes them:—

Opaque Liquid Storax.—This is imported from Trieste in casks or barrels holding about four hundredweight each. It is opaque, of a grey color, has the consistence of birdlime, and the odor of storax, but frequently intermixed with a feeble smell of benzol or naphthalin.

The substance met with in the shops, and sold to perfumers under the name of strained storax—*styrax colatus*—is prepared from liquid storax, by heating it until the water with which it is usually mixed is evaporated, and then straining it. During the process, it evolves a very fragrant odor. The impurities are stones, sand, *et cetera*.

In consequence of **Petiver**'s statement, storax has been supposed to be the produce of a species of *liquid ambar*. But several facts are unfavorable to this opinion:—Firstly: Its vanilla-like odor allies it to the products of *styrax officinale*, and at the same time separates it from all authentic products of the genus *liquidambar*. Dr. **Wood**, for example, found the genuine juice of *L. styraciflua* very different to that of liquid storax; and the fluid resin, called liquidambar, has no resemblance to it. Secondly: **Marquart** analyzed a specimen of the genuine resin of *L. altingia*, and obtained a volatile oil somewhat like styrol, and a substance similar to styracin; but their composition he found to be entirely different; for while styracin consists of $C_{24} H_{22} O_2$, the liquidambar resin was composed of $C_{16} H_{22} O_2$.

Pellucid Liquid Storax.—*Storax liquide pur*, **Guibourt**.—This substance was sold to Dr. **Pereira** under the name of *balsam* or *balsam storax;* and he was informed that it had been imported in jars, each holding fourteen pounds. It agrees with the *pure* or *fine liquid storax* of **Hill**, and the *styrax liquida finissima* of **Alston**. Professor **Guibourt**, to whom Dr. **Pereira** sent a sample, at first regarded it as balsam of liquidambar; but its odor has subsequently induced him to rank it among the products of *styrax officinale*. It is a pellucid liquid, having the consistence and tenacity of Venice turpentine, a brownish-yellow color, a sweetish storax or vanilla-like odor, entirely different from that of liquidambar. A few particles of bran or sawdust are intermixed with it. By keeping, it yields a white and acid sublimate on the sides of the bottle which contains it.

All the storax imported into this country comes from Trieste. The following are the results of **Reinsch**'s analyses of styrax calamita:—

	1. Styrax calamita.	2. Brown granular.	3. Reddish compact.
Volatile oil,	?	0·5	0·4
Resin,	41·6	53·7	32·7
Subresin,	?	0·6	0·5
Benzoic acid,	2·4	1·1	2·6
Gum-and extract,	14·0	9·3	7·9
Matter extracted by potassa,	15·0	9·6	23·9
Woody fibre,	22·0	20·2	27·0
Ammonia,	traces	stronger traces	strongest traces
Water,	5·0	5·0	5·0
Styrax calamita,	100·0	100·0	100·0

The volatile oil was obtained by digesting the distilled water of storax with ether. The *solid* oil was white, crystalline, and fusible; its odor was agreeable, its taste aromatic and warm. The *fluid* oil had not so penetrating an odor.

Simon found liquid storax to consist of styrol, cinnamic acid, styracin, a soft, and a hard resin.

Storax is used in medicine, and is called a stimulating expectorant. In its operation it is closely allied to balsam of Peru and benzoin, but it is less powerful than the latter. It is used also as a detergent in the form of ointment.

DRAGON'S-BLOOD.—This is a deep red resin, imported from the East Indies. The finest kind is in large red drops, and is said to be the produce of *calamus draco*. It also occurs in masses of various degrees of purity, and in sticks, enveloped in palm leaves; but, according to **Brande**, these varieties appear to be more or less sophisticated. The article when pure is of a dark blood color, soluble in alcohol and ether, and in alkalies. When this balsam is subjected to dry distillation, it fuses, yielding water, acetin, and three and a half per cent. of benzoic acid; as the temperature increases, carbonic oxide and carbonic acid are formed, and a reddish-brown oily fluid distils over, which is a mixture of several bodies. **Glenard** and **Boudault** isolated from this two carbides of hydrogen, which they named *dracyl* and *draconyl;* the former, the Editor, in conjunction with **Hofmann**, proved to be identical with *toluol;* and the latter, **Blyth** and **Hofmann** showed to be *metastyrol*.

LIQUIDAMBAR is obtained from the *liquidambar styraciflua*, a tree which grows in Mexico, Louisiana, and Virginia. Some specimens are thin, like oil, and others are thickish, like turpentine. It is transparent, amber-colored, has an agreeable and powerful smell, and an aromatic taste, which is somewhat pungent in the throat. Boiling alcohol dissolves it almost entirely. It contains a good deal of benzoic acid, some of which effloresces whenever the resin hardens with keeping.—*Ure.*

TOLU BALSAM is the produce of *Myrospermum toluiferum*, a tree growing on the mountains of Tolu and Turbaco, and on the banks of the Magdalena, between Garapatas and Monpox. It exudes during the heat of the day from incisions in the bark; and is imported chiefly by way of New York and Jamaica, generally in tin canisters, but sometimes in earthen crocks and in calabashes. On its arrival it is soft and tenacious, but gradually hardens; it is translucent, brown, very fragrant, and has a sweetish taste, softening between the teeth. When heated, it fuses and takes fire, diffusing an agreeable odor. FREMY states that the components of Tolu balsam are the same as those of the Peru balsam. These balsams only differ in their degree of organization, and especially in the facility with which the balsam of Tolu becomes resinified. The tree which yields the balsam of Tolu was formerly called *Toluifera balsamum.* RICHARD having carefully investigated the characters of the genus Toluifera, found that, with the exception of the fruit, they were identical with those of the genus now called *Myrospermum;* and as RUIZ states that the balsams of Tolu and Peru are obtained from the same tree, the *M. peruiferum* has been adopted by several writers, and by the London College, as the source of both balsams. RICHARD made a distinct species of the tree yielding the balsam of Tolu, and it is now called *M. Toluiferum.*

The Editor, some years ago, when distilling the balsam of Tolu, remarked the following:—There passes over at first aqueous vapor, and when the temperature is sufficiently elevated, a large quantity of benzoic, with a slight admixture of cinnamic acid, which solidifies immediately in the recipient into a white crystalline mass. When the fluid distilling over no longer solidifies, the receiver is changed; a yellow liquid condenses, which is a mixture of toluol and benzoic ether. The crystalline mass collected in the first receiver contains likewise a large quantity of the same liquid, which can be separated by mere distillation with water.

Balsam of Tolu is frequently adulterated with common resin. To detect this, pour sulphuric acid on the balsam, and heat the mixture, when it dissolves to a cherry-red fluid, without evolving sulphurous acid, but with the escape of benzoic or cinnamic acid, if no common resin is present; on the contrary, the balsam foams, blackens, and much sulphurous acid is set free, if it is thus adulterated.

PERU BALSAM.—As many readers of this work may feel deeply interested in the principal balsams, the Editor will give extracts from the excellent paper by Dr. PEREIRA, published in the *Pharmaceutical Journal*, on *Myrospermum Pubescens* and its medicinal products, *Balsamio*, balsam of Peru, and white balsam.

There is no article of the Materia Medica, the natural history of which is more obscure than that of the so-called Balsam of Peru; for in all the best modern pharmacological and botanical works, errors, confusion, and doubts, exist with respect to it.

Of the celebrated white balsam of America, European writers have little definite knowledge. It is mentioned, indeed, by most pharmacologists, but it is obvious from their statements that they are unacquainted with it; for some of them regard it as liquidambar, some as balsam of Tolu, and others as dry balsam of Peru; from all of which, as will be seen in the sequel, it essentially differs. Dr. STENHOUSE undertook the chemical examination of the white balsam, the result of which led to the discovery of a new organic principle.

The balsam is quite neutral to test paper, and has a peculiar agreeable odor like melilot. When it is digested in ordinary spirit of wine, a considerable portion readily dissolves; and when the clear extract is allowed to repose for a day, it deposits a quantity of large white crystals. They retain a good deal of adhering resinous matter; but they can be obtained perfectly pure by digestion with a little animal charcoal and repeated crystallizations from hot alcohol. When pure, they are hard and brittle, colorless, tasteless, scentless, and form broad thin prisms, more than an inch in length. Insoluble in hot and cold water; but are readily dissolved by hot alcohol and ether. To these crystals STENHOUSE has applied the name *Myroxocarpin*, the formula of which is $C_{48}\ H_{35}\ O_6$. It is a very indifferent substance, displaying no affinity for either acids or bases.

HISTORICAL NOTICE.—A brief historical survey of the most important works and papers relating to the balsams will make the reader fully comprehend the present state of knowledge with respect to these drugs, and the sources of the errors and obscurities which have hitherto encircled them.

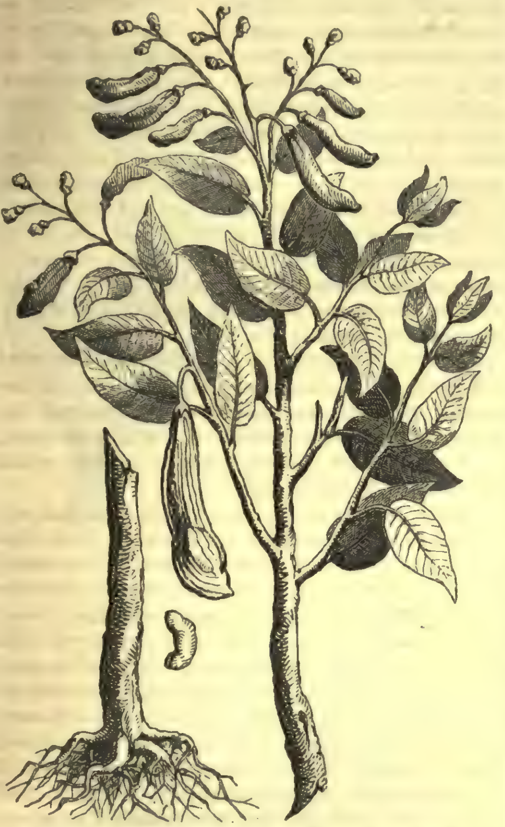
NICOLAS MONARDES, in whose work—the first edition of which was published at Seville in 1565—the earliest mention of Peru balsam occurs, calls it simply *balsamo*, and says that it is the produce of a tree growing in New Spain, and called by the Indians *xilo.* He describes the tree as being larger than the pomegranate, having leaves like those of nettles, and bearing a narrow, white, thin siliqua, or pod, of the length of a finger, and thickness of a sixpence, and which encloses at the end one bitter odorous seed, about the size of a pea. He mentions two modes of procuring the balsam—one by incision into the rind of the stem, the other by boiling the branches in water; and he afterwards notices its physical properties and valuable medicinal qualities.

Although MONARDES was never in America, and must, therefore, have obtained his information from the reports of others, yet there is reason to believe his statements to be faithful.

The next writer who describes the balsam and the tree yielding it, is FRANCISCO HERNANDEZ, a Spanish physician and naturalist, who resided from the year 1593 to 1600 in Mexico and New Spain. He notices four balsam trees: one called *Hoitziloxitl*, a second termed *Iluaconex*, and a third denominated *Maripenda*, and the fourth found in the province of Tolu. Of these four, the first one appears to be identical with the tree which yields the so-called balsam of Peru, and a copy of HERNANDEZ's drawing of it is therefore subjoined—Fig. 140.

HERNANDEZ states that the Indian balsam tree—*arbor balsami Indici*—is called by the Mexicans *hoitziloxitl*, because it abounds in resin. He describes it as being of the size of a lemon tree, and having leaves which are larger than those of the almond, but rounder and more acuminate. The flowers are yellow, and are placed on the summits of the branches. The seeds are whitish, oblong, somewhat contorted, and lodged at the extremity of the oblong shells or fruits, which are longer and broader than the leaves. The tree, he says, is a native of warm regions, as Panuco, and was cultivated by the Mexican kings in the Hoaxtepec gardens. He gives two methods of obtaining the balsam, and states that the seeds yield, by pressure, an oil which resembles in flavor and odor that obtained from bitter almonds and peach kernels.

Fig. 140.



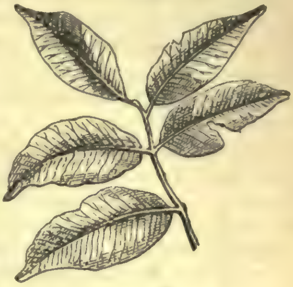
After the death of Linnæus, who had always been peculiarly anxious to ascertain the plant which yields this balsam, Mutis sent to the younger Linnæus specimens of the leaves and flowers of a plant which, he said, grew in the warmest provinces of South America, and yielded Peruvian balsam. A description of this plant, to which the name of *Myroxylon peruiferum* was given, was published in the *Supplementum Plantarum.*

Annexed is a woodcut—Fig. 141—of the leaflets of *Myroxylon peruiferum.*

The figure is about one-third the natural size of the leaf. On the authority of Mutis, many writers declare the above to be the source of balsam of Peru.

The first accurate botanical description of the tree which yields balsam of Peru, was given by Ruiz—in 1792—in his *Quinologia.* His memoir was translated into English by the late Mr. A. B. Lambert, and published by him in 1821, with a correct engraving of the plant, in his *Illustration of the Genus Cinchona.* Ruiz says the tree is known in Peru under the name of *Quinoquino*, and he calls it Myroxylon peruiferum, considering it to be identical with the *M. peruiferum* sent by Mutis to the younger Linnæus. This, however, would appear to be an error, Ruiz's plant being, according to Kunth and De Candolle, a distinct species from that of Mutis. Ruiz states that the tree grows in the mountains of Panatahuas, in the forests of Puzuzu, Muna, Cuchero, Paxatin, Pampahermosa, and in many other countries near the river Maranon, in low, warm, and sunny situations; but the Indians of these places do not collect the balsam.

Fig. 141.



Ruiz says the balsam of Quinoquino is procured from incisions made in the tree at the beginning of spring, when the showers are gentle, frequent, and short; it is collected in bottles, where it keeps liquid for some years, in which state it is called *white liquid balsam.* When the natives deposit this liquid in mats or calabashes, which is commonly done in Carthagena and in the mountains of Tolu, after some time it condenses and hardens into resin, and is then denominated *dry white balsam*, or *balsam of Tolu*, by which name it is known in druggists' shops.

Dr. Pereira had two authenticated balsamic substances obtained from this tree: one procured from the stem by incision, and known in commerce as balsam of Peru, the other obtained by expression from the pericarp, and called *white balsam;* but the latter in no way resembles the balsam of Tolu of European commerce, and can scarcely be the white balsam alluded to by Ruiz. Mr. Skinner—whose firm, Klée, Skinner, and Co., Guatemala, largely exports balsam of Peru to Europe—never heard of any other balsam obtained from this tree. It is remarkable, however, that Mr. Klée speaks of the white balsam as being *balsam of Tolu.*

In 1823 appeared the sixth volume of Humboldt, Bonpland, and Kunth's *Nova Genera et Species Plantarum.* In this work the plant of Ruiz and Lambert, called by Ruiz *M. peruiferum*, Linnæus, is denominated *Myroxylum pubescens*, and the designation *Myroxylum peruiferum* is retained for the plant sent by Mutis to Linnæus. These distinctions have been adopted by De Candolle, who, however, has substituted Jacquin's designation of the genus *Myrospermum* for *Myroxylon* or *Myroxylum.* But it is most unfortunate that the specific name *peruiferum* should be retained for a plant which does not yield the so-called Peruvian balsam.

In 1834, M. Bazire, a French merchant, who lived for many years in Central America, informed Guibourt that the so-called balsam of Peru was not the produce of Peru, but of the coast near Sonsonate. He also gave him some of the fruit of the tree which yields the balsam; but which, being deprived of its membranous wings, Guibourt failed to recognise as the fruit of *M. pubescens—M. peruiferum* of Ruiz and Lambert—and he therefore inferred that it was the produce of a different species. More recently, however, he has expressed an opinion that it is the fruit of the *Myroxylon peruiferum*, Linnæus. But on this point he has fallen into an error, the fruit being that of *Myrospermum pubescens* of De Candolle.

It may be here observed that M. Bazire's account is quite accurate.

Such was the state of uncertainty which existed on this subject, when Mr. Skinner undertook to clear up the mystery, by procuring for Dr. Pereira specimens of the tree and balsams from Central America, and by furnishing him with much valuable written and verbal information. By him the following facts were elicited:—

Firstly, That the tree which yields the so-called balsam of Peru and the white balsam, is the species described and figured by Ruiz and Lambert, *Myrospermum pubescens*, De Candolle.

Secondly, That *black balsam—balsam of Peru of commerce*—is obtained by incision from the stem.

Thirdly, That the *white balsam* is procured from the fruit by pressure.

Fourthly, That commerce exclusively obtains both of these balsams from the so-called Balsam Coast in Central America.

Dr. Pereira, writing further on the *Myrospermum* of Sonsonate, from which balsam of Peru, white balsam, and balsamito, are obtained, believed the plant to be identical with that figured by Lambert, and which, according to both Kunth and De Candolle, is *M. pubescens*. A careful examination of the specimens in the British Museum, from which Lambert's figures were drawn, led him to doubt the identity of his plant either with the Sonsonate species, or with the *pubescens* of Kunth and De Candolle. For the present, therefore, the plant will be designated the *Myrospermum of Sonsonate.*

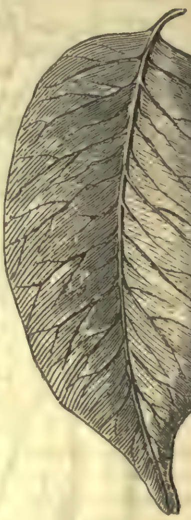
The specimens which Dr. Pereira received, consisted of branches, leaves, and fruits. The flowers were not met with.

The *branches* are terete, warty, but otherwise smooth, ash-colored, or ash-brown.

The *leaves* are alternate, petiolate, and imparipinnate. The common petioles appear to the naked eye devoid of hairs, but, when examined by the microscope, are found to be covered with a few short ones.

The *leaflets* are from five to eleven, alternate, with short petioles. Fig. 142 represents one of these leaflets in its natural size. Exclusive of foot-stalk, their length varies from about two to three and a half inches; and their greatest width, from one to one and a half inch. The most usual size is three inches in length, and one and a quarter to one and four-tenths of an inch in breadth. Their general shape is oblong or oval oblong, in some cases ovate. They are round, or very slightly tapering, not cordiform at the base. Superiorly they contract abruptly into an emarginate point. To the naked eye, the partial petioles and mid-ribs appear devoid of capillæ but when examined by the microscope, short lymphatic hairs, having a glossy or resinous appearance, are distinctly visible on them; and the partial petioles appear somewhat rough from transverse rugæ. The leaflets are elegantly marked by rounded and linear pellucid spots; the lines being usually parallel with, or in the direction of, the primary veins. To see the spots, the leaflets must be held up against a strong light, and examined by a magnifier.

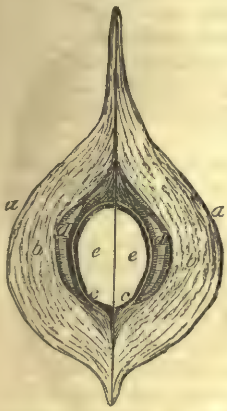
Fig. 142.



The *fruit* is a one-celled, one-seeded, winged, indehescent pod, called by some a samara, by others a samoroid legume. The fruit-stalk is naked at the base, but is amply winged superiorly. The fruit, including the winged foot-stalk, varies in length from about two to four inches; the usual length is three and an eighth, or three and a quarter. At the peduncular extremity, the fruit, or rather its winged foot-stalk, is rounded, or very slightly tapering, unequal sided; at the summit it is enlarged, turned, and rounded with a small point—the remains of the style—at the side. The mesocarp is fibrous; but immediately exterior to the endocarp, it contains, in receptacles, a yellow oleo-resinous or balsamic juice; which, by age, hardens and resinifies. Ruiz, Kunth, Endlicher, and De Candolle, describe this juice as immediately surrounding the seed, and being between it and the lining—endocarp—of the shell; but this is a mistake, it is exterior to the endocarp. The principal part of the balsam resides in the two receptacles or *vittæ*, one placed on either side; but if a transverse section of the fruit be examined by the microscope, numerous receptacles of the more or less dried balsam are perceived in all parts of the mesocarp. In the two larger receptacles, the balsam is usually found in the liquid state; but sometimes the walls of the receptacles are lined with the crystallized balsam—*myroxocarpin*. That the balsam resides in the mesocarp, and not in the cavity of the fruit, is proved by the cross section, which shows that the paries of the cavity of the fruit is continuous with the two sutures. The seed lies loose and dry in the cell of the pericarp, and is covered by a thin, white, membranous coat—testa. The cotyledons are yellowish and oily, have an agreeable odor, like that of the tonka-bean or melilot, and a bitter taste, somewhat resembling that of bitter almonds. By digesting the seeds in ether, a tincture is obtained, which yields, on evaporation, a very agreeable-smelling, amber-colored, soft extract, the odor of which resembles that of the cotyledons. Fig. 143 is a cross section of the fruit and seed—magnified:—*a a*, epicarp; *b b*, mesocarp; *c c*, endocarp; *d d*, large vittæ, or lacunæ, containing balsam; *e e*, cotyledons.

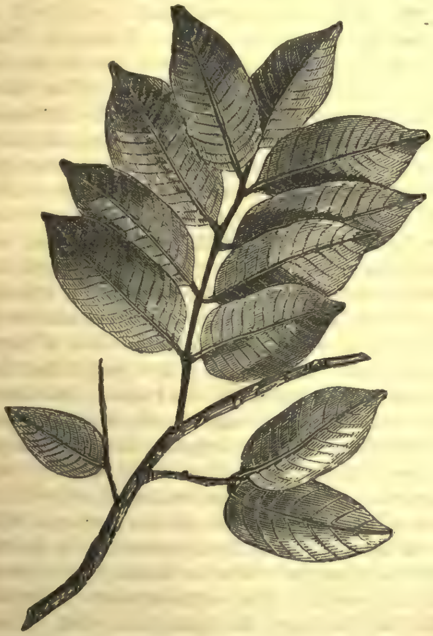
Some of the fruits given to Mr. Alfred Smee were sown by him in a pot, and placed in his hothouse. Several of them have produced thriving plants. A leaf of one of the plants thus raised, consists of five alternate leaflets, marked with pellucid dots and lines. To the naked eye, all parts of the leaves appear quite smooth; but when examined by the microscope, the general and partial petioles, the midribs, and the edges of the leaflets, are seen to be covered with small, reddish, appressed, lymphatic hairs. The lamina of the leaflets is emarginate, but the summit of the midrib, crowned by a small bush of hairs, projects, on the dorsal surface, beyond the lamina, and gives the appearance of a minute pointlet or mucro. As the leaflets dry, this pointlet appears to be shrinking and becoming brown. As the leaf grows, it probably falls off.

Fig. 143.



In the annexed sketches, Fig. 144 shows a leaf-bearing branch of the Myrospermum of Sonsonate, about one-third the natural size; Fig. 145, a fruit-bearing branch; Fig. 146, vertical section of the fruit; Fig. 147, lateral section of the fruit, showing the seed *in situ*.

Fig. 144.



The Myrospermum of Sonsonate so closely agrees in general with Pavon's *M. balsamiferum*, that Dr. Pereira was at first led to believe the two plants to be identical; and he was the more inclined to this opinion from the circumstance that, in one of the communications which he received from Sonsonate, the *Myrospermum* from that place was called *Myroxylon balsamiferum*.

Lambert's figure appears to have been made up from different specimens in Pavon's collection, and not from any one exclusively. Unfortunately, there is reason to suspect that the leaves of at least two species are contained in the collection under the same name, for in some of them the pellucid spots are exclusively round, in others round and linear. *Myroxylon balsamiferum*, Pavon; figured by Lambert as M. peruiferum, Linnæus. Fig. 148—*a*, flower, magnified; *b*, the curved ovary, surrounded at the base by the calyx.

Fig. 145.

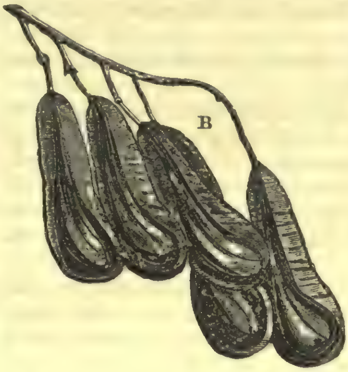
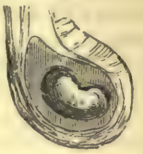


Fig. 147.



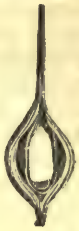
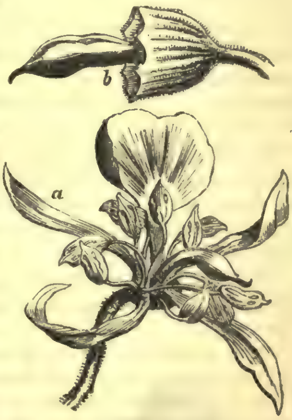


Fig. 146.

Fig. 148.



Firstly, *The size and shape of the leaves.*—Many of the leaves of Pavon's specimens—those which agree best with Lambert's figure—are larger than those of the Sonsonate plant. The shape also is different. While in the Sonsonate plant the prevailing shape is the oblong, that of Pavon's is more oval; again, the leaves of the former are more generally rounded at the base, and less tapering at the summit, than those of the latter.

When specimens of the two plants are placed side by side, the principal difference observed is the larger size and more tapering summits of the M. balsamiferum.

Secondly, *The size and shape of the fruit.*—The pods of Pavon's are longer than those of the Sonsonate plant. The average length of the latter rarely exceeds three or three and a quarter inches, while those of Pavon's specimen vary from four to six

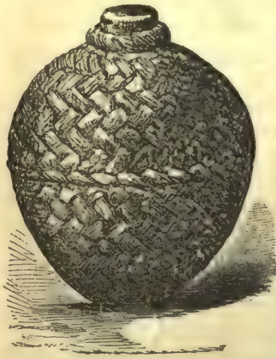
In the shape there is also a difference. In Pavon's plant the fruit is nearly of equal width, the two margins of the wings being parallel, or nearly so, throughout the greater part of the length of the pod. Thus, many of the pods are of the same breadth—about one and a quarter inch—for more than four inches of their length. In the Sonsonate specimens, on the other hand, the margins of the fruit diverge from each other in the direction from the peduncle towards the summit, and in no two parts has the pod the same width.

Central America is the country of the Myrospermum Sonsonate. It grows on the Balsam Coast—between 13° and 14° north latitude, and 89° and 90° west longitude—in the state of Salvador, where the black and white balsam are exclusively obtained from it. HERNANDEZ gives Panuco as one of the places where it grows; and CLAVIGERO states that it is common in the provinces of Panuco and Chiapan. Various medicinal products are obtained from the tree. By making an incision in the trunk of it, a liquor exudes called the *black balsam*, an admirable remedy for effecting the speedy cure of wounds of every description: from the flowers the *spirit of balsam* is made; the seeds or nuts produce the *oil of balsam*, an excellent anodyne; and the capsules yield the *white balsam*. From these simple kinds the *tincture* or *essence of balsam* is extracted. It is generally termed *balsamito*, and was a discovery of DON JOSE EUSTAQUIO DE LEON, director of the mint in Guatemala, who published a description of the many virtues of this peculiar medicine. The only medicinal products of the tree are, black balsam—commonly called balsam of Peru—white balsam, and balsamito.

The *Sonsonate of St. Salvador; black balsam.*—This is the balsam of Peru of commerce—*Balsamum Peruvianum*, Latin. At Sonsonate it is termed *black balsam—balsamo nigro.* It is sometimes denominated the *black* or *liquid balsam* of Peru. Sonsonate or St. Salvador black balsam of commerce—balsam of Peru of the shops—is exclusively the produce of the Balsam Coast, which extends from the Ajacutla to the Port Libertad on the Pacific side of Central America.

The Sonsonate or St. Salvador *white balsam—balsamo blanco.*—This is often confounded with the balsam of Tolu. White balsam is obtained at Sonsonate by pressure, without heat, from the interior of the fruit and seed. It is imported in globular earthen jars, surrounded by a kind of plaited matting—Fig. 149—closed by an earthen stopper. The jar enclosed in the matting is about a foot high, and ten and a half inches in diameter, and contains about twenty pounds of balsam, which is partially concreted or crystallized on the sides. When removed from the jar, and put into a white glass bottle, it closely resembles, in appearance, strained American or Bordeaux turpentine. It is semi-fluid, or a soft solid, and by exposure becomes firmer. It is quite devoid of the fragrant cinnamon odor of the balsams of Peru and Tolu.

Fig. 149.



According to Mr. SKINNER'S account, obtained during his sojourn in Guatemala, the balsam was obtained thus:—A fire was made around, but at some little distance from the balsam tree; the bark was then cut, and a stick slipped in between it and the wood, so as to partially separate these two parts of the stem from each other. By working the stick about, somewhat in the manner of a pump-handle, the balsam, aided by the heat, exuded, and was absorbed by rags.

The only purification to which balsam of Peru is subjected in England, is one of a mechanical kind, that is to say, by standing, the balsam is allowed to separate from the water and any other impurities, and is then drawn off.

Mr. SARAVIA, of Sonsonate, having been requested to question the Indians respecting the production of balsam, replied:—The method used to extract the balsam from the trees, is to make several incisions, over which pieces of old cloth or rags are placed for the absorption of the juice; when they are well soaked, they are put in water to boil, until they have discharged the greatest part of the imbibed balsam. The liquid is then allowed to settle sufficiently, until the water rises, leaving the balsam at the bottom; next, the upper stratum is carefully poured off, and the balsam put into *tecomates*—gourds—although at this time it is not very pure. The rags are then put into *redes*—little bags of cords—which are strongly twisted to wring out any remaining balsam into the *tecomates*. When purchased, it is necessary to clean it again, because it still contains water and other impurities which some Indians will mix with it to gain greater weight.

THE BLACK BALSAM OF PERU.—The method of obtaining black Peruvian balsam has always been a subject of controversy. When STOLTZE, in the year 1824, published his *Treatise on the Black Peruvian Balsam*, he could not be convinced that it was obtained by a sort of *distillatio per descensum*, and not by decoction or spontaneous exudation, as he stated. Dr. MARTIUS, of Erlangen, found his opinion corroborated by Dr. PEREIRA'S; but that the balsam should, by boiling the rags in water, rise to the surface, and thus be removed, is impossible, for it has a specific gravity of from 1·150 to 1·160, and cannot, therefore, float on water in a state of ebullition. If a solution of common salt, that is to say, a liquid of greater specific gravity were employed, the balsam would then certainly float, but, at the same time, its agreeable odor would probably disappear, in consequence of the high temperature required for boiling the saline solution. As, moreover, the cinnamic acid contained in the black balsam is soluble in water, the greater portion of this acid would be given out to the liquid employed for the exhaustion of the rags. Now and then single drops of water, and sometimes even entire layers were supernatant *in the tin boxes, in which formerly the black Peruvian balsam was exported;* but this trifling portion of water Dr. MARTIUS has always considered to be the product of *distillatio per descensum*, for he never found in it, by evaporation, anything but cinnamic acid, formerly regarded as benzoic acid. Moreover, whence arises in many of the tin boxes the sediment of several inches found in them after remaining at rest? Furthermore, what is the reason that the *tinctura balsami Peruviani* is sometimes of a lighter, and sometimes of a darker wine-yellow color, according as it is prepared from a lighter or darker colored balsam? This originates, no doubt, from the higher or lower degree of heat employed in the *distillatio per descensum.* Several years ago, a sort of black Peruvian balsam was in the market, which, on running down the glass, *appeared of a reddish-brown color*, was more fluid, and yielded, even after continued standing, a proportionately insignificant sediment. All this tends to show, that besides the various kinds of Myrospermum used for yielding the balsam, the higher or lower degree of heat employed in its preparation, must contribute to vary the quality obtained.

STOLTZE says he has never observed in his operations the products of a descending distillation, but there is a great difference between such a process and a gentle *distillatio per descensum.* Moreover, it must not be forgotten that the plants which yield the black Peruvian balsam, grow in a country which is in the highest degree favorable to the exudation of resinous juices from vegetals. Besides, the formation of cinnamic acid takes place, as it appears, only by the absorption of oxygen, or by an increased temperature.

As Bordeaux carries on a considerable trade in black Peruvian balsam, Dr. MARTIUS sought and received the following account from a friend there:—*Balsamum Peruvianum nigrum* is generally exported from Sonsonate and Ajacutla—Central America—in jars, and is mostly transferred to Europe in tin boxes, when it is at the same time deprived of water, mucilage, and salt, which is generally effected in a bathing tub. For some time past, the English have begun to take possession of this article, and import it from the eastern part of Central America, by way of Belise or Greytown. A captain, who formerly imported two hundred jars of balsam, saw them being filled, and was not a little astonished on finding here that water had separated during the voyage. In a fresh state the balsam is greenish and more fluid, than after having been kept for some time, when it flows with a golden-brown, and runs down the glass with a reddish color.

From the preceding communication it appears, firstly, that black Peruvian balsam, sold retail, has already undergone a purification; secondly, that the Peruvian balsam, as imported from America, contains water, mucilage, and salt; and thirdly, that the balsam in a fresh state is not only more fluid, but likewise possesses a greenish color.

The characters to be attended to in judging of its genuineness are, its pure odor, complete miscibility with alcohol, by which the absence of fixed oil is shown, and its suffering no diminution of volume after mixing with water, proving that there is no spirit present. A sign of its purity is, that one thousand parts of it should saturate seventy-five parts of crystallized carbonate of potassa.

Among the substances fraudulently mixed with Peru balsam, castor oil and copaiba balsam are the most difficult to discover. ULEX recommends the following method:—Ten drops of Peru balsam are mixed in a watch-glass with twenty drops of concentrated sulphuric acid, and then diluted with water. If the balsam is pure, a brittle resin is thus obtained; but when adulterated with castor oil and similar substances, this residue is proportionately soft. Sulphurous acid is likewise disengaged, which is not the case when the adulterating substance is copaiba.

Considerable variations in the specific gravity of Peru balsam must not be altogether overlooked. It usually varies between 1·14 and 1·16, but when sophisticated with as much as twenty-five per cent. of castor oil, it is much lower.

To detect copaiba balsam, the substance is to be heated in a small tube retort, until a few drops of a yellow oily liquid have passed over, which takes place at a temperature of 374° Fahr. This distillate is acid, and soon deposits crystals of cinnamic acid. If the balsam used was pure, it solidifies completely; but when adulterated with copaiba, the crystals float in copaiba oil. The distillate is then to be saturated with caustic potassa, and the solution of cinnamate removed by means of blotting-paper. The drops of oil which are then left, mix quietly with iodine if the balsam was pure, but cause a violent action in the presence of copaiba.

An expert chemist could tell the copaiba by its smell; in general, the purity and strength of the odor of the Peru balsam, and its perfect transparency, are certain proofs of its goodness.

SKINNER gives the method employed by the Indians of Central America for extracting the balsam from the tree. They begin by making an incision from two to two and one-third inches broad, and from three and a half to four in length; they then raise the bark from the living wood, and afterwards apply there pieces of cotton rags, after having heated the tree by surrounding it with a brisk fire for a short time. When they tap the tree for the first time, they make the incision rather more than a yard above the ground, and when the liquor ceases to ooze out, they make a second incision by the side of the first one, and in the same manner, but a little higher up; and thus they continue making new incisions as fast as they become exhausted around the tree. In the course of ten or twelve days, the rags become thoroughly impregnated with a thick olive-brown liquid; they are then withdrawn, and subjected to a fresh process. The rags saturated with the balsam are collected together and placed in an earthen vessel, called olla or pot, with some water, and boiled for five or six hours. During this operation the balsam detaches itself, and, so long as the boiling continues, mixes with the water; but as soon as the liquid becomes cold, the balsam, being much heavier, settles, and the water floats over it; hence it is easy to separate them from each other. Before the water cools, the cotton rags are removed; but as they still contain a certain quantity of liquid, they are subjected to a more forcible pressure by means of a small machine, made with pieces of wood, cords, and tourniquets. Lastly, they collect all the balsam extracted from these rags, after subjecting them to pressure for several days; pour off the water, and put the balsam, which has now become dark and liquid, into a calabash, for the purpose of carrying it to market. The balsam which flows from the tree always contains a considerable quantity of water, and hence the necessity of boiling this liquor after it has been extracted.

Annexed is STOLTZE'S analysis of the balsam of Peru:—

	Per cent.
Brown slightly soluble resin,	2·40
Brown resin,	20·70
Oil—cinnamein,	69·00
Benzoic and cinnamic acid,	6·40
Extract,	0·60
Loss and moisture,	0·90
	100·00

BALSAMIC ETHERS.—SCHARLING, of Copenhagen, communicated to the Royal Danish Academy of Sciences a preliminary statement of some experiments made in order to produce ethers, by acting with potassa on various natural balsams. After having noticed the earlier investigations on Peruvian balsam, he observes that the formula given by FREMY for the composition of cinnamein, $C_{54}\,H_{26}\,O_8$, may be looked upon as $2\,C_{16}\,H_7\,O_2 + C_{22}\,H_{12}\,O_4$, of which the first member represents the formula for cinnamein given by PLANTAMOUR, and the second member that for cinnamic ether, which the latter chemist produced from Peruvian balsam. PLANTAMOUR, however, having used alcohol in his investigations, doubts might arise whether this had not occasioned the formation of the cinnamic ether. SCHARLING submitted one part of Peruvian balsam, and two or three parts of solution of potassa, of the specific gravity 1·3, to distillation, after the mixture had been left for twenty-four hours. The product consisted of water and two oily bodies, the one lighter, the other heavier than water. By drying and redistillation, the heavier liquid was obtained perfectly transparent, of high refractive power, of specific gravity 1·03, and with a boiling point of 401° Fahr. Immediately after the distillation, the smell was faint; but after having stood for a while, it became aromatic, like that of cinnamic ether.

Immersed in a refrigerating mixture of snow and rock salt, the whole remained liquid at 5° Fahr. The oily liquid, of less specific gravity, boiled at about 356°; its specific gravity was less than that of water; the smell not unlike aniseed; the taste sweetish, aromatic; cooled to 5° Fahr., the greater part congealed. Both these liquids are altered by distillation; for, even when heated in an oil-bath, they assume a light wax-yellow color before they begin to boil. As both these liquids thus offered great resemblance to cinnamic ether and peruvin, the same chemist tried to ascertain their identity with these substances, by treating them with hydrate of potassa and sulphide of carbon. Although the discoverer of xanthogenic acid, the late professor ZEISE, remarks, that ether and sulphide of carbon, with hydrate of potassa, do not give xanthogenate of potassa; yet it was presumed that this salt might be produced by treating compound species of ether with hydrate of potassa and sulphide of carbon. As this supposition has been fully confirmed with different kinds of ether—for instance, with acetic ether—SCHARLING mixed separately both the liquids produced by Peruvian balsam with powdered hydrate of potassa and sulphide of carbon. In both these experiments the mixtures congealed; and when samples of the saline mass were dried between paper, and then dissolved in water, and tested with salts of copper and lead, they furnished yellow xanthogenate of copper and white xanthogenate of lead. Hence there can be no doubt that the liquid of higher specific gravity contains cinnamic ether, obtained for the first time without any addition of alcohol. By distilling the solution of potassa which had been separated from the cinnamein, only traces of an oily liquid were obtained; the rest of the distillate appeared to be water. Hence it is evident, that even at the ordinary temperature, and by the influence of a solution of potassa, the combination which at a suitable temperature is converted into a species of ether, is decomposed. By distilling Peruvian balsam with water, no oil or ether, as is known, is produced. Since this possibly might arise from the boiling point of cinnamic ether lying too high, the last named authority distilled a portion of Peruvian balsam with a solution of chloride of sodium, and a smaller portion with a concentrated solution of chloride of zinc. The last distillation was performed by dropping the balsam gradually into the boiling saline solution. By this process, besides water, some cinnamic acid and a very small quantity of two liquid, oily, brownish bodies, the one of greater and the other of less specific gravity than water, were obtained. Both had an empyreumatic odor; and, when boiled with water, a quantity of crystals of cinnamic acid were produced on cooling. No trace of cinnamic ether could be discovered in this distillate. By subjecting Peruvian balsam to dry distillation, several oily liquids were obtained, containing a great quantity of cinnamic acid, as also water. The former crystallized on cooling, and was collected on a filter; the liquid that had passed through, after it had been dried over chloride of calcium and redistilled, was treated with powdered hydrate of potassa and sulphide of carbon. No traces of xanthogenic acid could be detected in this mixture.

A portion of Peruvian balsam was next operated upon with a solution of carbonate of soda. The aqueous solution obtained behaved like a solution of cinnamate of soda. The remaining substance was exsiccated, dry carbonate of soda added to it, and the mixture subjected to destructive distillation. The distillate resembled in appearance the products from the dry distillation of the Peruvian balsam; but in this traces of xanthogenic acid were found by suitable treatment. From these experiments, therefore, it is not to be concluded *that cinnamic ether pre-exists in the balsam, but that it is most likely formed by the action of strong bases.*

SIMON'S investigation on liquid storax eliminated a body which he called *styracon.* He found that, on treating liquid storax in the same manner as he had treated Peruvian balsam, he immediately obtained a distillate, from which, after standing for a while, a body separated, possessing all the properties assigned by him to styracon. Moreover, it easily dissolved in alcohol of 0·851 specific gravity. By treating the styracon with powdered hydrate of potassa and sulphide of carbon, xanthogenate of potassa was formed amongst other products. Hence it is supposed that the styracon constitutes a compound ether. From want of styrol, he examined how benzol would act with hydrate of potassa and sulphide of carbon. No xanthogenate of potassa was produced. Balsam of copaiba was next treated with hydrate of potassa, and then distilled. A considerable quantity of oil, which floated on the distilled water, was immediately obtained. When the water had been poured back and distilled a second time, the quantity of oil collected constituted about five ounces, and the distilled water about twenty. A pound of balsam and a pound and a half of solution of potassa—specific gravity 1·25—had been used. The oil did not appear to differ from that of balsam of copaiba which occurs in trade; but on treating these oils with hydrate of potassa and sulphide of carbon, no formation of xanthogenate of potassa could be perceived. By treating Venetian turpentine in a similar manner, an oily liquid was obtained, which, when dried over chloride of calcium, or lime, did not appear to be acted upon by powdered hydrate of potassa. For several hours after the addition of the potassa, the color of the liquid remained unaltered, and exhibited no change of temperature. On adding sulphide of carbon, a white saline mass was formed after some time, which gradually caused the whole mixture to congeal into a jelly. After twenty-four hours this jelly was thrown upon a filter; and when the greater part of the liquid which the mass contained had run off, the residue was most carefully pressed between paper. A part of the product thus obtained was dissolved after being dried; another portion was shaken with ether, in order to remove all adherent oil and resin. The ether was separated by filtration, and the saline mass, after being dried, was likewise dissolved in water. Both these solutions immediately afforded brown precipitates with chloride of copper, but which after some time became yellow.

With nitrate of lead, whitish-yellow precipitates were produced; and with several other solutions of salts, reactions similar to those of xanthogenic acid were obtained, except that all the precipitates had in general a somewhat darker color. This circumstance led to the supposition that an ether had been formed by the action of the potassa on the Venetian turpentine. The boiling point of the distillate was about 307° Fahr.; its specific gravity 0·87°; the solubility in alcohol of 0·823° specific gravity, was identical with that of common oil of turpentine.

These properties agree so nearly with those of ordinary turpentine oil, that the supposition of the liquid being a species of ether was abandoned; whereas it was presumed, that if Venetian turpentine was distilled with water, the oil obtained would exhibit the same relations to hydrate of potassa and sulphide of carbon as the above-mentioned liquid. Experiment gave an affirmative conclusion. Common oil of turpentine, recently distilled and well freed from water, was treated as above, the results, upon the whole, were the same; consequently, it is possible to produce, by the action of hydrate of potassa and sulphide of carbon, from pure turpentine oil, a combination possessing great resemblance to xanthogenic acid. But, in order to form this substance, it is absolutely necessary to have well-fused hydrate of potassa; because, in the state in which it is often met with in commerce, it contains too much water. The whole of the turpentine oil cannot be decomposed by the sulphide of carbon and hydrate of potassa. The same appears to occur in this decomposition as in the production of terpin; a part only of the turpentine oil enters into the new combination.

SCHARLING observed, that though it is asserted that all pure turpentine oil consists only of $C_{10} H_8$, and that the boiling point and the specific gravity are alike, yet the oil from Venetian turpentine appears in several respects to differ from the oil of common turpentine. Thus the last-mentioned oil is speedily colored by the hydrate of potassa, which is not the case with the oil of Venetian turpentine. The latter oil polarizes the light to the left; but only a rotation of 25° is required to produce the violet color. The same is the case with a saturated solution of chloride of dadyl in alcohol, when the dadyl has been prepared from Venetian turpentine.

Common turpentine oil also polarizes the light to the left; but, to produce the violet shade, a rotation of 70° is required. This also happens both with a saturated alcoholic solution of chloride of dadyl prepared from common turpentine oil, and the liquid part of that turpentine oil from which the compound resembling xanthogenate of potassa had been produced. The longer the turpentine oil has been kept, the more strongly is it acted upon by the hydrate of potassa. It is owing to this circumstance that at times it produces an increase of temperature of more than 108° Fahr., then forms a clear brown gelatinous mass, which appears in a great measure to prevent the production of the compound resembling xanthogenate of potassa. Even when common turpentine, recently rectified and dried over lime, is employed for the preparation of this salt, a much darker product is generally obtained than with oil from Venetian turpentine. By allowing the saline mass, which in general contains potassa and sulphide of potassium, to remain exposed to the air, the substance becomes clearer, and the precipitate produced by sulphate of copper turns yellow much sooner.

The compound resembling xanthogenate of potassa from *terpin* has not yet been obtained; whether it can be procured from *terpinol* remains undecided.

STATEMENT of the IMPORTS and EXPORTS of the different balsams, in pounds, at the ports of the United Kingdom, in the years 1849 and 1850:—

	1849.		1850.	
	Imported	Exported.	Imported.	Exported.
Canada balsam,.......	6,912	—	19,038	15
Copaiba "	64,400	53,536	53,200	20,944
Peru "	993	1,196	13,743	3,787
Tolu "	—	299	514	1,864
Other sorts,..........	526	—	1,233	—

STATEMENT of the IMPORTS and EXPORTS of the under-mentioned balsams at the ports of the United Kingdom, in the years 1851, 1852, and 1853:—

	1851.		1852.		1853.	
	Import.	Export.	Import	Export.	Import	Export.
Canada balsam,..	7,923	1,609	21,282	3,461	100	757
Copaiba " ..	69,440	17,024	125,552	26,208	117,040	31,920
Tolu " ..	2,994	208	4,048	623	8,610	1,678
Peru " ..	22,848	27,208	16,893	18,598	34,798	35,695
Other sorts,.....	145	—	319	—	4,443	—

BEER—*bière*, French; *bier*, German—is a malt liquor of any kind, or a spiritous liquor made from any farinaceous grain, but generally from barley, which is first malted and ground, and its fermentable substance extracted by hot water. This extract or infusion is evaporated by boiling in caldrons, and hops, or some other plant of an agreeable bitterness, added. The liquor is then allowed to ferment in vats. It is of different degrees of strength, and is denominated small beer, ale, porter, brown stout, *et cetera*, according to the quantity and nature of its ingredients. Beer is a name given in America to fermenting liquors made of various other materials; and when a decoction of the roots of plants forms part of the composition, it is called *spring beer*, from the season in which it is made. There is also root beer. In Britain, the term *beer* is applied in the same way to fermented liquors made from ginger, spruce, and molasses, as well as to that procured from malt and hops. In the time of TACITUS, whose treatise on the Manners of the Germans was written about the end of the first century of the Christian era, beer was their common drink: PLINY mentions it as being used in Spain, under the name of *cœlia* and *ceria;* and in Gaul, under that of *cerevisia*; he then proceeds to explain, that almost every species of corn has been used for the manufacture of beer. In Europe it is usually made from barley; in India from rice; in the interior of Africa, according to MUNGO PARK, from the seeds of the *holcus spicatus*, spiked or eared wall-hardy. These observations are corroborated by other authors of antiquity; and the *cerevisia* of PLINY evidently takes its name from *Ceres*, the goddess of corn—lexicographers doubting whether it ought not to be written *cererisia*. PLAUTUS more minutely calls it *Cerealis liquor;* that is, liquor used at the solemn feasts in honor of that goddess—the *harvest home;* and both he and COLUMELLA—a famous writer on agriculture, who flourished in the reign of CLAUDIUS, and whose work is therefore coeval with the invasion of Britain by that emperor—called this liquor *zythum*, which, if traced back to its Greek origin, is interpreted, *drink from barley.*

There is no department of the arts and manufactures where Chemistry has exerted a more decided influence than in brewing. In a state of society like the present, when philosophy and enterprise travel with giant strides, and when every branch of technology calls aloud for scientific aid, exact theoretical information cannot be too widely diffused. Notwithstanding the trite saying which has existed from time immemorial, *that any old woman can brew*, it is worthy of remark that few old women, even in literature, are chemists, fewer chemists are brewers, and fewer still are the brewers who, by attention to chemical transformations, have been able to increase the quantity of the useful extract from malt, and to reject the errors, both in theory and in practice, that eventually reduce the labor of the old-woman brewer to futility and loss.

Many operative brewers, in some of the largest town establishments, even now ridicule and despise the idea of chemistry being in any way connected with the art of brewing. Such ignorant prejudices only perpetuate bigotry, and cause an enormous waste of property; the progress of useful art is impeded; and its promoters are ungenerously maligned by a spirit, which knows not the limited range of its own capacity.

In the brewing of beer, the first process of importance which comes under notice is that of malting. Ere this can be proceeded with, however, the grain on which to operate must be chosen, and it is hoped the few following remarks will be found of service, more especially to the inexperienced.

SELECTION OF BARLEY.—Owing to the difference of constituents, energies, and vital functions in grain, according to the diversities of soil, climate, seed, or husbandry, in harvesting, stacking, and thrashing, it becomes necessary that the maltster's skill and experience should be equal to the important task in selecting those samples of corn which, by good management, will produce the richest and most uniform malt; he ought not, moreover, to be restricted by laws which are often arbitrary and unjust, but have free scope in fully exercising his judgment and varying his practice, according to the quality of his grain or other attendant circumstances.

The barley most suitable for conversion into malt grows in large hedgeless tracts of light calcareous soil, and crops, excellent in quality, also thrive on rich loam. Much, however, depends upon the seed: the best possesses a bright, clean, thin, wrinkled husk, tenaciously adhering to a plump, round, well-fed kernel, which, when bruised, appears chalky and sweet, with a germ full, and of a pale yellow color. The barley most profitable for malting is the *rath*, or early ripe, which matures several weeks before other sorts, and is that which agriculturists ought to select, not only on account of its forwardness, but also because it makes superior malt, in consequence of the thinness of its skin and the lusciousness of its nature. Barley is not in a proper condition for malting until it has sweated and seasoned in the stack; if stacked too damp, it will generate so much heat as to destroy the germ. The maltster should be careful in avoiding mixed barley, old and new, as such can never grow evenly or work well together.

The medicinal qualities of barley may not be quite so well known as are its nutritive properties, and therefore a brief glance at these may not prove unacceptable to the reader. In the first degree they are cooling and drying, gently repercussive, abstersive, diuretic, and anodyne, appropriated to the lungs and veins, and galactogenetic. Each variety possesses the same virtues.

Adept brewers, from their long experience, know the best kinds of grain to select.

MALT AND MALTING.—In various parts of Peru, large quantities of maize are converted into *chica;* and it is a remarkable fact, that the grain used in all such cases has been made to undergo the process of malting, a proof that the making of malt must have been known to the inhabitants of that country from a very remote period.

Oats, peas, beans, maize, buckwheat, and common wheat, are all capable of being malted, and have been experimented upon, but barley is most prized for this purpose.

The heaviest grain is recommended, as, if in good condition, it gives malt of corresponding gravity.

What is here intended to be understood by the heaviest malt is, that it shall be of a tender and friable nature throughout, and without hard ends, which are generally more similar in composition and properties to barley than to malt. The perfect article is not always attainable, even with the best skill or management, and it would, on this account, be improper to pass lightly or carelessly over such an important subject.

Malt may be very heavy and yet hard, too much so to bear the name of malt; and the inexperienced may be greatly deceived, unless they have sufficient knowledge to discriminate between the several varieties sent into the market. At the present time the difference is from one to eight shillings per quarter; within the last thirty years, however, it has been as high as from one to sixteen shillings per quarter.

If malt is short of the extract, in comparison with that of the best quality, it is also deficient of fine flavor.

The utmost skill is required to produce a malt of abundant sweetness and friability; when these are attained, it will never be too heavy.

If the brewer is also a maltster, as he ought to be, both in knowledge and in practice, he can procure malt any color he pleases; but even if he be not, there will be no great difficulty in giving the necessary order for any peculiar tint or flavor, either pale, amber, brown, or any intermediate shade.

Much space might be occupied in giving a full dissertation on this subject; it will therefore be treated of in as concise and clear a manner as is possible, so as to include the principles and main features of the most approved systems.

The whole process is comprised under these successive operations: *steeping*, *couching*, *flooring*, and *kiln-drying*.

Steeping.—Without the first—steeping—the grain will not vegetate, which is requisite before its nature can be changed.

The steeping is usually performed in large wooden or stone cisterns, into which the grain to be malted, already screened down and nicely levelled, is shot; it must be charged with liquor to six or seven inches above the barley, and, although the grain has been well cleaned, there will always be some light grains and other matter floating on the surface of the liquor, which must be skimmed off, otherwise, if retained, they would impair the quality of the article, and also the flavor of the beer made from it. However, the improved cultivation of the soil, and the new varieties of barley, have of late years done away with the necessity of skimming.

In consequence of the absorption of moisture, the grain swells about one-fifth in bulk, and increases about fifty per cent. in weight, one hundred pounds of barley thus becoming one hundred and fifty.

The object of steeping is to expand the farina of the barley with humidity, and thus make the seed fit for germination, when subsequently exposed to the air. Too much steeping is injurious, because it prevents the germination at the proper time, in consequence of the air being excluded whilst the superabundance of water is spontaneously evaporating; it is hurtful, also, in extracting a portion of the saccharine matter. The maceration is known to be complete when the grain may be easily perforated with a common needle, and is swollen to its full size; or if a barley-corn, when taken between the thumb and fingers and pressed, sheds its flour upon them, it is ready; but if it continues entire, or its substance exudes as a milky juice, it is either, in the first instance, not sufficiently steeped, or, in the latter, the steep has been too long continued, and the grain is spoiled for germination.

In warm weather it sometimes happens, that, before the grain has completely swelled, the water becomes acescent; this circumstance, which is very soon discovered, may be immediately remedied by drawing off the foul liquor by means of the tap at the bottom of the cistern, and replacing it with fresh cold water. No harm is done even if it be renewed three times during one steep.

The time of steeping, which varies according to the temperature and other circumstances, requiring in winter a longer and in summer a shorter period, is reckoned technically by the term *tide*, each being of twelve hours' duration. In winter it may extend over five and a half or six tides, from the time the liquor is put into the cistern to the time of letting, sixty-six or seventy-two hours; at others it will cease to swell much sooner, but, as a general rule, it should lie in the cistern until it will no longer swell, after which, the liquor being drawn off, it should be left to drain for six hours before it is emptied into the couch. If now the skin, which is somewhat loosened, be partially removed from the kernel, and the two ends are slightly pressed, the latter will be seen to be partly separated.

The Couch.—The water being drawn off, and a fresh quantity occasionally passed through, to depurate the grain from any slimy matter which may have been generated, it is laid upon the stone flag-floor of the couch in square heaps, from twelve to sixteen inches in depth, and left in that position for twenty-four hours.

The bulk of the grain being greatest at this time, the revenue officers may, if they think fit, gage it. The surface of the barley is now so entirely freed from moisture, that it does not feel damp. By degrees, however, it becomes warm, its temperature being 10° above that of the atmosphere, and it gives out an agreeable fruity smell. If at this time the hand is thrust into the heap, it gets bedewed with moisture, and at this sweating stage the germination commences; the fibrils of the radicle first shoot forth from the tip of every grain, and a white elevation appears, which soon separates into three or more rapidly increasing radicles. About a day after this appearance, the plumula—acrospire of the maltster—peeps forth from the same point, and would proceed under the husk until it appeared at the other end of the seed, as a green leaflet; but this never happens in malting, as the operation is finished before it takes place.

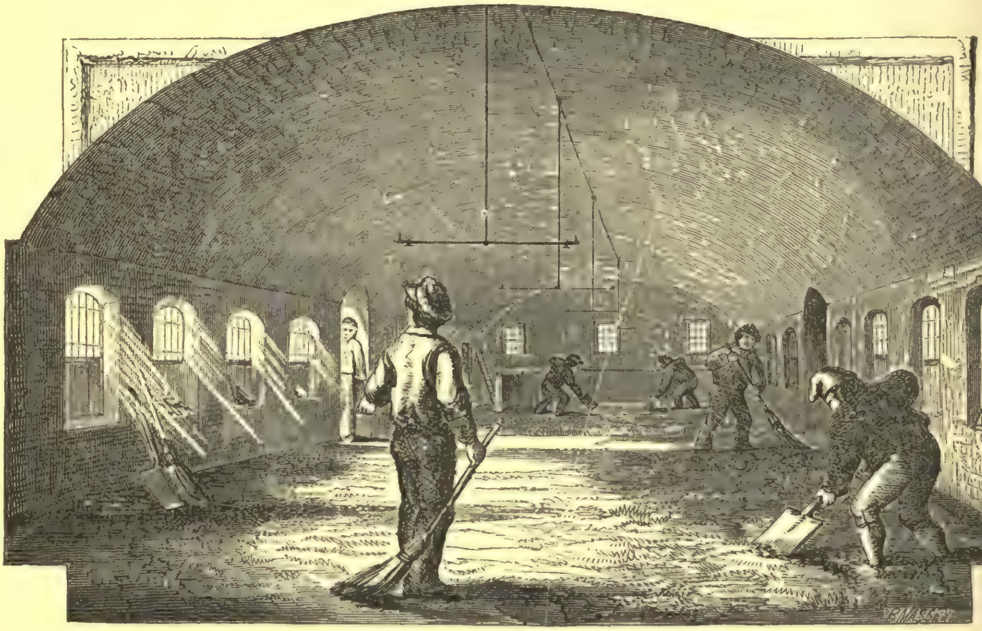
About ninety-six hours after the barley has been taken out of the steep, the heat is the greatest, consequently the radicles increase in length with great rapidity, and must be checked by artificial means, which constitute the chief art of the maltster.

The barley must be spread out thinner upon the floor, and turned several times a-day—as shown in Fig. 150—the interior being always brought, by the spades of the workmen, to the surface. The depth, originally fifteen or sixteen inches, is lessened slightly at each turning, till it is at last not more than three or four inches. Two spadings per day are generally requisite. At this period of spreading or flooring, the temperature in England is about 62° Fahr., but in Scotland only 56° or 57°.

The rudiments of the stem, or the plumula, sprout forth about a day after the appearance of the radicles.

To a limited extent the barley absorbs oxygen and emits carbonic acid, just as animals do in breathing; the grain loses from one and a half to three per cent. of its weight upon the malt floor, a portion of this being due to waste particles. As the acrospire creeps along the surface of the seed, the constituents undergo a remarkable alteration. The gluten and mucilage in a great degree disappear, the color becomes whiter, and the substance so friable that it crumbles into meal between the fingers. This is the great object of malting, which is accomplished when the acrospire has reached the end of the seed. At this period the growth must be completely stopped. The duration of the germination in England may be reckoned fourteen days; but in Scotland eighteen or even twenty-one are required, owing to the lower temperature of the couch.

Fig. 150.



The shorter the period within these limits the better, as there will be a quicker return of capital, and the malt produced is superior. In dry weather it is sometimes necessary to moisten the barley upon the couch.

If an offensive odor, somewhat resembling that of rotten apples, be observed to arise from the couch, it is a bad omen, showing that either the quality of the barley was inferior, or that, through carelessness, the workmen have crushed a number of the grains in turning.

On this account, when the weather causes germination too quickly, it is better to arrest it by spreading the heap out thinner than by turning it too often.

Comparing different samples of barley, it will be found that the best develop the acrospire quicker than the radicles, and thus give rise to a greater production of the saccharine principle; this conversion advances and keeps pace with the acrospire, so that the portion of the grain to which it has not reached remains in its unaltered starchy state. It is never complete till the acrospire has attained the opposite end to that from which it sprung; hence one portion of the corn may be *sugary*, while the other is still tasteless. If the grain was allowed to vegetate beyond this term, the radicles being one-third of an inch long, the future stem would become visibly green, it would shoot forth rapidly, the interior of the grain would appear milky, a complete exhaustion of all its useful constituents would ensue, and nothing but husk remain.

In France, the brewers, who are generally their own maltsters, seldom leave the barley on the couch longer than eight or ten days, which is too short a period, even when allowance is made for the extra warmth of the climate; hence the wort, made from the same quantity of malt, is much inferior to that of the English brewer.

At the conclusion of the germination, the radicles have become once and a half as long as the barley, and are so contorted that the corns hook one into another, but the acrospire is just beginning to make its appearance.

A moderate temperature is best fitted for malting; it cannot, therefore, be *well* carried on in the heat of summer or the cold of winter. Malt floors should be placed in substantial thick-walled buildings, the more concealed from the rays of the sun the better, so that a temperature of 59° or 60° Fahr. may uniformly pervade the interior. They are said by some to be better when sunk slightly under the surface of the ground, provided that the situation is dry.

During germination, portions of the glutinous constituent of the grain disappear, which it is conjectured have passed into the radicles, while a portion of the starch is converted into sugar and mucilage. The change is similar to that which starch undergoes when dissolved in water, and digested at a heat of about 160° Fahr. with a little gluten. The thick paste becomes by degrees liquid, transparent, and sweetish to the taste, the solution containing sugar and gum mixed with some unaltered starch. At the same time the gluten undergoes a change and becomes acescent, so that only a certain amount of starch can be thus modified by a quantity of gluten. By the artificial growth upon the malt floor, the whole of the gluten and albumen is not decomposed, and only about one-half of the starch is changed into sugar; by a continuance of the germination, the remainder would only assist the growth of the roots and stems, but it is nearly altogether converted into sugar, without any very great waste of substance, in the brewer's operation of mashing.

If the grain is suffered to sprout in the couch, it will never be even afterwards, as those corns which are sprouted will attract more than their proper share of moisture; moving and turning in due time will, however, retard this, and cause each corn to shoot almost simultaneously.

The Flooring.—In this operation the grain is turned inside out from the couch into the bed, which is made to occupy two or three times as much space as the former, according to the temperature. It may lie here for about six hours, observing in the interim whether the grains are commencing to shoot; or, if this is not the case, giving it a gentle turning, and spreading it out thinner, before the expiration of the period named; it may be laid all the width of the floor, and permitted to remain for another six hours, when all the healthy corns will be sprouted; it is then again thinned, and after this, while it is in full vigor, often turned; by this means the root is kept short and bushy, and retains the moisture as long as is requisite, to the period of its withering, if the process be of sufficient duration, *without sprinkling.*

The root begins to fade about the eleventh or twelfth day.

If, on taking a handful of the grain from the floor, it smells faint, and the skin is glossy or wet, it requires turning. After this it will smell fresh, and the grain, instead of being glossy, will be dry. If the turning is omitted at the proper time, the root will be of unequal length.

On the grain beginning to wither, it may be spread out thicker, to generate a little more warmth, and to mellow it, still keeping it frequently turned, to prevent a glossy appearance, until the moisture is further expelled, and also to retard the progress of the acrospire.

The grain, when ready for drying, must easily rub to meal between the fingers, after being deprived of the skin.

Kiln-drying.—When the malt has become perceptibly dry to the hand upon the floor, it is taken to the kiln and hardened with artificial heat, to prevent all further growth, and enable it to be kept, without fear of change, for use.

The malt should be evenly spread upon the drying cloth, or floor, in a layer varying from three to ten inches in thickness, according to the variety which is to be produced, and a heat of from 90° to 100° Fahr. steadily maintained, till the moisture is for the most part driven off. During this time the malt must be turned over, at first frequently, and, towards the conclusion, every third or fourth hour. When nearly dry, the temperature of the kiln should stand between 145° and 165° Fahr., and this heat must be maintained till the grain has acquired the desired color.

The fire is now allowed to die out, and the malt is left on the kiln till sufficiently cool, this result being greatly accelerated by the stream of cold air rising up through the bars of the grate. Thoroughly dry brown malt may, however, by damping the fire, be taken hot off the plates, and cooled in some contiguous apartment. The kiln-drying should not be hurried; many persons occupy two days in the operation. The malt, when prepared, must be kept in a dry loft, where it can be occasionally turned over till used.

The temperature of the kiln should, in all cases, be most steadily maintained, and, when required, gradually elevated.

If the drying commences with too great a heat, the outer part of the grain hardens, and prevents the interior moisture from evaporating; should this be driven off by too high a temperature, the husk will, in all probability, split, and the farina become horny and very refractory in the mash.

It is preferable, therefore, to brown malt by a long-continued moderate heat, than to apply a strong one for a shorter period, which might carbonize a portion of the mucilaginous sugar, thereby deteriorating the value of the product.

In this manner the sweet, very often changes to a bitter principle.

During the drying, the roots and acrospire of the barley become brittle, and are, by the friction of turning, *et cetera*, broken off, and are afterwards separated by a fine wire sieve—Fig. 151, in the next page. This operation is termed cleaning.

The *bulk* of good malt exceeds that of the barley from which it was fabricated, by about eight or nine per cent.

The benefit derived from kiln-drying is not merely confined to the expulsion of the moisture, a portion of the starch which was unchanged is by it converted into sugar in a double or twofold way: firstly, by the action of the gluten upon the fecula at an elevated temperature; and, secondly, by the incipient roasting the starch is subjected to, giving it a kind of gummy nature.

This is illustrated by the fact that malt, freed from moisture as much as possible in a dry atmosphere without heat, yields much less saccharine extract than that dried ordinarily. Moreover, kiln-dried malt has a peculiar, agreeable, and faintly-burnt taste, probably from some empyreumatic oil generated in the husk, and which imparts its flavor to the beer, at the same time that it assists in preserving it. The skilful preparation of the malt must necessarily exercise a very great influence on the worts which are prepared from it. If the germination be pushed too far, a portion of the valuable matter is wasted, while, if it is not carried on sufficiently long, the malt will be too raw, and much of its starch will remain insoluble; if it is too highly kiln-dried, a portion of its sugar will become caramelized and bitter; and if the sweating was irregular or imperfect, much of the barley may be lumpy or useless.

Fig. 151.

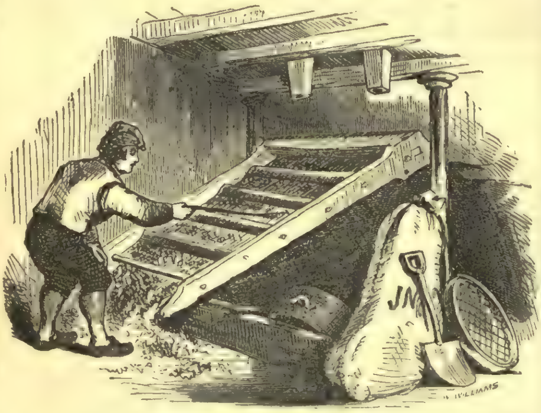


Fig. 152.

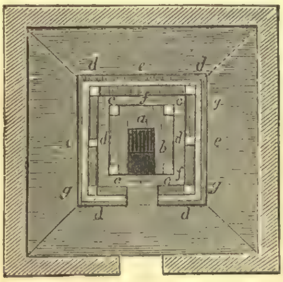


Fig. 153.

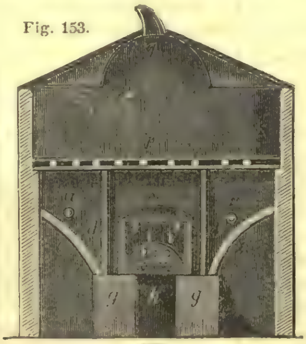


Fig. 154.

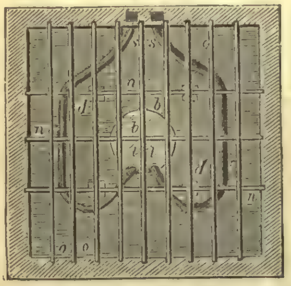
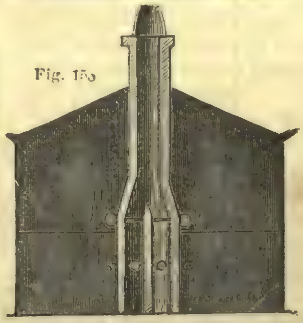


Fig. 155.



The grains of good malt are round and full, break freely between the teeth, have a sweetish taste, an agreeable smell, and are full of soft flour. They give no unpleasant taste on being masticated; are not hard, so that they will give a free white streak, like chalk, when drawn contrariwise to the fibres of wood; and, lastly, will swim on water, as is not the case with unmalted barley.

Malt-kiln.—The construction of a well-contrived malt-kiln is shown in Figs. 152, 153, 154, 155: the first being the ground plan; the second, a vertical section; the third, a horizontal, and the fourth, a vertical section in the line of the malt plates. The same letters in each of the figures are indicative of similar parts.

In the middle, upon a wall of brickwork four feet high, is supported a cast-iron cupola-shaped oven, and beneath it are the grate and ash-pit. The smoke escapes through two equidistant pipes into the chimney. *a* is the grate, nine inches below the sole of the oven, *b; c c c c*, are four strong nine-inch pillars of brickwork bearing the stone lintel, *m; d d d d d d*, are similar supports for the girder and joists, upon which are laid perforated plates; *e* indicates a vaulted arch on each of the four sides of the kiln; *f* is a space between the kiln and the side arch, allowing of the inspection and cleaning of the kiln; *g g*, walls, on which the arches rest, on each side of the kiln; *h*, the ash-pit; *k* is the furnace-door; and *l l* are junction pieces connecting the pipes, *r r*, with the kiln.

These smoke-draughts rest about three feet from the walls, and a similar distance from the malt-plates, upon iron supports secured to the arches. They are indicated in the vertical section—Fig. 153—by the letters *u u;* at *s s*—Fig. 155—they enter the chimney, to which is supplied two register or damper plates, intended to regulate the draught. These registers are represented by *t t*; the lintel, *m*—Fig. 153—is intended to cause the heat to spread laterally, instead of ascending in one mass in the middle, and prevents any combustible particles from falling upon the iron cupola; *n n* are main girders of iron supporting the joists, *o o*, of the same material, upon which the perforated plates, *p*, lie; *q* is a vapor pipe in the middle of the roof, allowing the steam of the drying malt to escape.

This kiln may be heated either with coal or wood. The size is about twenty feet square, but it may either be proportionally enlarged or diminished, as seems advisable. The perforated floor should be large enough for the contents of one couch or steep to be spread out upon.

It can be heated by means of steam pipes, laid irregularly, or in parallel lines under it, or a wire-gauze web might be extended upon such pipes. This steam apparatus might, without danger, be supported by joists of timber. For drying the pale malt of the brewers, this plan is well adapted.

Gas-Drying.—A patent was recently granted to Mr. HALLEWELL of Leeds, for improvements in malting, in consequence of drying by gas instead of the usual process. This invention is stated to augment the yield of malt twelve per cent., that is, something like one bushel out of every eight malted.

The malt to be dried is laid on an ordinary perforated floor of iron plates, and very small jets of gas are applied within 5¼ inches of its under side.

During the first twelve hours the temperature rises to 70° Fahr.; at the expiration of forty hours, it reaches 120° without any increase in the consumption of gas.

When this degree has been attained, the malt is, comparatively, perfectly dry, and quite pale. It is very fine in appearance, and remarkable for its peculiar sweetness; and being freer from moisture than most malt kilned in the usual way, as on analysis it only gave 5·89 per cent.—see page 243—it passes through the rollers in grinding in one-fourth less time than the ordinary product. The cost of exsiccation is said to be about two per cent. over that by the common method; but as the produce is above twelve per cent. more, there is a clear advantage.

According to Mr. HALLEWELL, the worts are drawn so closely from his malt as to be below four pounds per barrel gravity. He says:—If the worts were drawn as low from cinder-dried malt, the acid of the liquor would be so strong as to be quite nauseous and injurious.

The advantages and beneficial effects of this new system of desiccation, no doubt, arise in part from the small quantity of water which the malt contains, and the absence of sulphur, of which there is always a certain amount in the coke ordinarily used for drying; the result is the evolution of sulphurous acid, which certainly affects the malt, bleaching it, and leaving some sulphuric acid behind, which, when water free from carbonate is employed, seriously interferes with the fermentation.

Regarding the truth of the foregoing statement of the increase consequent upon the use of the gas-dried malt, the Editor has had no immediate opportunity of judging; but it has been corroborated by very eminent brewers in London and elsewhere. This invention must be of material importance in other cases than that of making beer; but especially brewers will benefit by it, and more so when the duty on malt is high.

MALTING IN MUNICH.—The barley is steeped till the acrospire seems to be quickened; a circumstance indicated by a swelling at the end of the grain which was attached to the footstalk, as also when, on pressing a pile between two fingers against the thumb nail, a slight projection of the embryo is perceptible. As long, however, as the seed-germ sticks too firm to the husk, it has not been steeped enough for exposure on the underground malt floor. Nor can deficient steeping be safely made up for afterwards, by sprinkling the malt-couch with a watering-can, which is apt to render the malting irregular. The steep-water should be changed repeatedly, according to the degree of foulness and hardness of the barley: first, six hours after immersion, having previously stirred the whole mass several times; afterwards, in winter, every twenty-four, but in summer, every twelve hours. It loses none of its substance in this way, whatever vulgar prejudice may think to the contrary. After letting off the last water from the stone cistern, the Bavarians leave the barley to drain in it during four or six hours. It is now taken out, and laid on the couch floor in a square heap, eight or ten inches high, and it is dexterously turned over, morning and evening, so as to throw the middle portion upon the top and bottom of the new-made couch. When the acrospire has become as long as the grain itself, the malt is carried to the *withering* or drying floor, in the open air, where it is exposed in dry weather, during eight to fourteen days, being daily turned over three times with a winnowing shovel. It is next dried on a well-constructed cylinder, or flue-heated malt kiln, at a gentle, clear heat, without being browned in the slightest degree, while it turns friable into a fine white meal. Smoked malt is entirely rejected by the best Bavarian brewers. Their malt is dried on a series of wove-wire horizontal shelves, placed over each other; up through the interstices or perforations of which, streams of air, heated to only 122° Fahr., rise from the surfaces of rows of hot sheet-iron pipe flues, arranged a little way below the shelves. Into these pipes the smoke and burned air of a little furnace on the ground are admitted. The whole is enclosed in a vaulted chamber, from the top of which a large wooden pipe issues, for conveying away the steam from the drying malt. Each charge may be completely exsiccated on this kiln in the space of from eighteen to twenty-four hours, by a gentle uniform heat, which does not injure the diastase, or discolor the farina.—*Ure.*

In concluding the account of Malting, the Editor cannot refrain from making a comparison between the present system and the ingenious and excellent one lately patented by Mr. W. L. TIZARD, the eminent mechanical and consulting engineer of London.

It is well known that even an ordinary malting establishment includes an extensive range of buildings, containing a cistern, a couch, extensive floors, and the kiln. Mr. TIZARD'S newly-invented malting apparatus consists of a vertical cylinder, containing a series of wire trays, provided with sprinkling and turning apparatus and steam pipes, vacuum and plunge pumps, vacuum and pressure gages, thermometer, *et cetera*, and worked throughout the whole year with 75 per cent. less labor, and 50 per cent. less fuel than the old one. Experienced men admit, that of late the harvests have been so unpropitious, that the farmer is unable to secure his barley crop sufficiently dry for the purpose of the maltster, and the latter asserts that it is necessary to dry or sweat the grain artificially on a kiln, previous to its saturation with water in the cistern. The process of sweating is, however, neglected, on account of the great trouble it gives, or from there not being an extra kiln provided for the purpose. Hence the malting is commenced in a slovenly and imperfect manner. The temperature of the steeping liquor, and the number of hours allowed for the saturation of the grain, are also disregarded as matters of routine, notwithstanding that they are points of very great importance as affecting its manufacture into malt. With the new apparatus, the process is commenced and finished in one vessel, which is a cylinder, occupying but one-twentieth the area of a malt-house. The barley gravitates from the stores above into each tray; after which the door is screwed up, and the cylinder made air-tight. The conversion of the grain into malt commences thus :—A current of steam is passed through a series of tubes lying under the bottom of each tray, which imparts its caloric to the grain, by which all superfluous moisture and atmospheric air escape from each corn in the form of vapor. When the contents of the cylinder are heated to the temperature of about 100° Fahr., the vacuum pumps are put in motion, by which such vapor is extracted, and a partial vacuum created. The atmospheric pressure being thus removed, and the dilatation of the grain effected, a vacuity necessarily exists in the pores and interstices of each corn. In this favorable condition it imbibes steeping liquor at a temperature of 53°. Thus the steeping is accelerated, and a perfect saturation produced. The grain is now allowed to germinate; but throughout this interesting process, the laws of nature are subject to the controlling hand of science, which has here brought to its aid all the mechanical means necessary to achieve the great object of the maltster, namely, that of thoroughly exposing and making available the whole farina of the corn, without which the article would be imperfect. This is effected and kept within the range of proper temperatures by a steady sprinkling and evaporation of cold water, accompanied by the constantly evolving carbonic acid, which are together removed by the vacuum pumps. On the other hand, its temperature might be increased, and the process accelerated, by occasionally applying the plunge pumps, which subjects the manufacture to atmospheric pressure. The great revenue arising from the malt duty will, to a moral certainty, render this invention as acceptable to her Majesty's Commissioners of Excise, and the Chancellor of the Exchequer, as to the honest maltster; inasmuch as it admits of being locked up, like a rectifier's still, as soon as the barley is introduced, and need not be opened till the manufacture is complete, and the malt ready to be removed to the stores; so that the whole process is proof against fraud, and the daily supervision of the officers of Excise could be dispensed with.

Space will not admit of a disquisition on the comparative merits of the old and new processes of couching, flooring, sprinkling, germinating, turning, heaping, and withering, but a brief description of the curing or finishing process, termed *drying*, cannot be dispensed with. This can be accomplished without the painful experience of having destroyed the vitality of the grain by the barbarous shovel, or the soles of the feet; by excessive light; cold or hot currents, or other incidental causes. Presuming, then, that the new apparatus has supplied the necessary moisture and atmospheric air, and abstracted all superfluous caloric, and the carbonic acid gas generated by the germination of the grain, which it cannot fail to do to perfection, the drying is performed as follows:—Steam is passed through the pipes, speedily raising the temperature of the contents of the cylinder to 90° or 100°. The vacuum pumps are also put in requisition, which immediately extract the steam as it flows out of the grain, preserving a partial vacuum on its exterior, during the withdrawal of the whole of the moisture. The malt is thus thoroughly dried in a distended form, and its original plumpness is preserved. It is acknowledged that the palest malt produces the largest amount of extract, and that it cannot be too pale if properly desiccated. The apparatus thus briefly alluded to, has been designed by a practical maltster and brewer, with the view of advancing one of the most important of our national manufactures, and one which is most susceptible of improvement, the common malting processes being rude and unsatisfactory in the extreme. Here is a complete set of apparatus to enable an intelligent operator to control the various processes of sweating, steeping, and converting the farina of his corn into sugar, and of exsiccating it to perfection, without imparting the least possible color or contraction of the grain. Indeed, malting is now reduced to a science, and cannot fail to meet with the support of the Government, and the most intelligent of the malting and brewing communities. For the pale ale brewer, this invention ought certainly to be invaluable, and the Editor would strongly recommend the leading firms at Burton and elsewhere to introduce the apparatus into their establishments.

Before proceeding further, it will be advisable to dwell very concisely on the composition of raw and malted barley.

The analysis of barley-meal has been made by EINHOFF; but the results which he obtained are so extremely discordant with those obtained by others, that they do not at present seem to be worthy of confidence.

PROUST affirms that barley contains a peculiar proximate principle, which, from the Latin name of the grain, has been denominated *hordein*. He describes it as a yellow, granular, woody powder, in appearance very much resembling sawdust; and says that it disappears in great quantity during malting, being resolved chiefly into starch and sugar. Does it not disappear wholly?

Annexed is the mean of ten analyses of barley performed by HERMBSTADT :—

	Centesimally represented.
Water,	10·48
Husk,	11·56
Gluten,	4·92
Albumen,	0·35
Starch,	60·50
Sugar,	4·66
Gum,	4·51
Oil,	0·35
Soluble phosphates, *et cetera*,	0·36
Loss,	2·31
	100·00

PROUST states that barley-meal contains—

Hordein,	55·0
Starch,	32·0
Sugar,	5·0
	92·0

Dr. T. THOMSON gives no hordein, but—

Starch,	88·0
Sugar,	4·0
	92·0

The analyses of PROUST and THOMSON agree exactly, only one takes the 88·0 to be solely starch; while the other assumes it to be a peculiar principle and that body.

The same statement is applicable to the principal constituents of malt, as given by these chemists, thus:—

	Proust.	Thomson.
Starch,	56·0	69·0
Hordein,	12·0	—
	68·0	69·0

The sugar found in the barley was, no doubt, the result of the action of some of the reagents employed by the above chemists on the starch.

EINHOFF'S analysis gives sugar in the same proportion as PROUST and THOMSON, but represents the quantity of starch as more than double that found by the former.

Dr. THOMSON is of opinion that the hordein, instead of being a proximate principle, is merely starch in a peculiar state, somewhat similar to the fibrous matter of potatoes, malting having the effect of converting it into starch and sugar by destroying a certain unknown glutinous substance, which holds the particles firmly together.

The presence of a singular substance in barley-meal in so great a quantity as more than fifty per cent., its being woody and insoluble in water, both cold and boiling, its disappearing during the malting, and the increase of gum, sugar, and starch in consequence, are properties not attributable to any component part of the grains with which chemists have hitherto been acquainted. Hence, hordein has been, and is now, admitted by many to be a peculiar substance. According to GREGORY, its composition is $C_{12} H_8 O_8$, or $C_{12} H_{10} O_{10}$.

If this analysis be correct, it is almost impossible to view hordein as a principle; it seems rather to be an allotropic modification of starch. It is very probable that this state is owing to some impurity or extraneous matter, and that, could this be removed, it would be found to consist of starch only. There is no doubt that, at some future period, the number of the principles now regarded as peculiar will be reduced, and many of them proved to be identical with each other, *only* existing under different circumstances.

The amount of inorganic matter in different specimens of barley, varies very considerably. This might be anticipated from the fact, now generally admitted, that the nitrogenized or nutritive principles of grain or seeds, bear a relation to the phosphoric acid present; thus, if the quantity of the latter be small, it follows that the amount of nitrogen is proportionally deficient, and the nutritive effect of the grain will be comparatively low in the scale, because the solubility of the albuminous matters, and, therefore, their capability of being carried into plants, appears to depend on the presence of the phosphates.

Dr. R. D. THOMSON says—In the analyses which have been published of this nature, the manipulators have omitted to state whether the husks were included in the grain burned by them. In the following results the omission has been filled up:—

	Barley Flour.	Barley with Husks.		
	R. D. Thomson.	R. D. Thomson.	Horsford.	Way.
Inorganic matter per cent., ...	4·02	3·20	2·70	2·34 .. 2·48

HORSFORD'S is the mean of ten, and WAY'S of four experiments.

The following was found to be the composition of the ash of barley and malt:—

	Centesimally represented.	
	R. D. Thomson.	
	Barley.	Malt.
Potassa,	16·00	14·54
Soda,	8·86	6·08
Lime,	3·23	3·89
Magnesia,	4·30	9·82
Oxide of iron,	0·83	1·59
Phosphoric acid,	36·80	35·34
Sulphuric acid,	0·16	—
Chlorine,	0·15	trace.
Silica,	29·67	28·74
	100·00	100 00

The composition of a sample of barley, and of malt made from it, thus showing the alteration in the grain by malting, is here given:—

	Barley.		Malt.	
	Natural state.	At 212°.	Natural state.	At 212°.
Carbon,	41·64	46·11	42·44	43·93
Hydrogen,	6·02	6·65	6·64	7·00
Nitrogen,	1·81	2·01	1·11	1·29
Oxygen,	37·66	41·06	43·08	46·51
Ash,	3·41	4·17	1·68	1·27
Water,	9·46	—	5·05	—
	100·00	100·00	100·00	100·00

The mean of a number of experiments relative to the loss which barley sustains by malting, indicated nineteen per cent.

The whole of the loss is not solid matter, as barley uncrushed contains 13·1 per cent. of water; and malt, in the same condition, 7·06 per cent. Mr. E. E. HOLDEN, student in the Editor's college, found in ordinary cinder-dried malt, 7·68 per cent.

There thus remain thirteen per cent. of solid loss.

A mean of several trials gave for the ash of barley 3·0; and for that of malt, 2·52 per cent. Now, as one hundred of the former are equal to eighty of the latter, the quantity of ash which malt should contain is 2·42, if the loss of organic and inorganic matter was equable, which it is observed to be, almost approximately, from this experiment; for the relation of the ash which has disappeared, or 0·48 per cent., bears almost the same proportion to the organic matter removed, as the total quantity of ash in barley does to the whole of the organic matter in that grain. Thus, barley contains eighty-four per cent. of *dry* organic matter and three per cent. of ash, while malt has lost 0·48 per cent. of ash, and 12·52 of organic matter, and by calculation—

$$\text{As } 3 : 0·48 :: 84 : 13·4.$$

A remarkable coincidence, as if proving that water is incapable of removing the inorganic portion of plants, until the organic matter has undergone such a change as to allow the ash to separate.

From the above, the loss sustained by barley in malting may be stated thus:—

Water,	6·00
Saline matter,	0·48
Organic matter,	12·52
	19·00

At the request of the Editor, who was desirous of ascertaining the amount of soluble matter extracted from malt by mashing, Mr. E. E. HOLDEN performed an experiment on the small scale, but as proportional with ordinary operations as possible, and found that, on repeatedly treating it with water, at an average temperature of 150° Fahr., 14·5 per cent. of residue, technically termed *brewer's draff*, was obtained, showing a loss of 85·5 per cent., water included, or 300 pounds per quarter of malt.

The composition of fresh draff—brewer's grains—is thus given by FROMBERG:—

	Centesimally represented.
Water,	75·85
Gum,	1·06
Other organic matter, chiefly husk,	21·28
Organic matter, containing nitrogen-protein-compounds,	0·62
Inorganic matter,	1·19
	100·00

From Mr. HOLDEN'S experiment and FROMBERG'S analysis of the draff, it would appear that, when the mash is properly managed, the whole of the available or useful matters in the malt are dissolved out by the brewer.

The ash left, on burning the draff, consists of—

	Centesimally represented.
Chlorides and sulphates,	7·60
Phosphates of potassa and soda,	2·11
Phosphates of lime and magnesia,	48·00
Silica,	41·51
Loss,	0·78
	100·00

WATER.—Good water in a brewery is a great desideratum, and the reader's attention is now directed to this subject.

Perhaps nothing in nature is more variable in character than this apparently simple fluid, which is not the *aqua pura* which it seems, and which many believe it to be, but a heterogeneous mixture of alkaline and metallic salts, acids, gases, and occasionally even animal and vegetal matter, some being held in chemical union, and others in mechanical suspension. Pure water, or *oxide of hydrogen*, is attainable only by art.

Some brewers prefer soft and others hard water, whilst a few are quite indifferent on this point.

Were the density of the worts, and the value of cold water, for refrigeration and other purposes, properly considered, there would be little hesitation in their choice; and it is of importance to arrive at a correct conclusion on this point; for, though a brewer already established can seldom choose a different spring or stream, the case is much altered when the site of a new brewhouse is to be selected.

Water free from saline matter, or that holds it in very small quantity, is unfit for the brewery. The softest is in the state of snow, which, according to BERGMAN, is destitute of all gaseous bodies, so that fish cannot live in it.

The Editor does not deem it necessary to give a long dissertation upon this liquid, as nearly every one at all acquainted with brewing knows, that water which contains a large quantity of gypsum—sulphate of lime—earthy carbonates, and *no organic matter*, is best adapted for his purpose.

Many, no doubt, wonder why hard water answers so much better in the preparation of malt than soft. A few reasons, to account for this, may not be unacceptable to the reader.

Dr. HASSALL says:—During ebullition, the excess of carbonic acid in the water, by which the carbonates of lime and magnesia are retained in solution, is expelled, and those salts are precipitated. Again, the alkaline phosphates present in malt have the power of converting sulphate of lime into phosphate, which is thrown down; an alkaline sulphate, which is soluble, being synchronously formed. The greater part of the phosphate of lime produced is redissolved in the acid generated during the fermentation; consequently the water, from being hard, thus becomes comparatively soft, and in this state is well suited for extracting the active properties of the malt and hops.—*Hassall.*

This is entirely speculative, and is not based on experiment; nevertheless, the theory is ingenious.

Another advantage in the use of hard water presents itself, which is, that more saccharine matter can be left in the beer, by which the fulness and flavor will be increased, and the liability to become acid prevented.

Water loaded with organic matter, like that of the Thames, is a decided loss to the brewer, as the vegetal and animal remains are decomposed during brewing, and carry with them some portion of the strength of the wort, besides rendering it and the beer liable to spoil.

Messrs. ALLSOPP and SONS, Messrs. BASS and Co., Messrs. SALT and Co., and other eminent Burton brewers, have long been celebrated for the quality of their beer, and many conjectures have been made to account for the excellence and superiority of the article brewed in that locality. The success depends in a very great measure upon the quality of the water used; the consequences of which, in brewing, have been scientifically elaborated. It is a very hard water, remarkable for its quantity of earthy sulphates and carbonates; and, *à priori*, it would be considered but ill adapted for the purposes of the brewer. This is not the case, however, as long experience has shown.

The following analysis by Dr. BÖTTINGER, brewer to Messrs. ALLSOPP and SONS, expresses the composition of the water used in that celebrated establishment, and conveys at once an idea of the general properties of this important menstruum:—

	Amount of ingredients in the imper. gallon. Represented in grains.
Chloride of sodium,	10·12
Sulphate of potassa,	7·65
Sulphate of lime,	18·96
Sulphate of magnesia,	9·95
Carbonate of lime,	15·51
Carbonate of magnesia,	1·70
Carbonate of iron,	0·60
Silicic acid,	0·79
	65·28

Some years ago, Mr. COOPER of London analyzed some water taken from a well at the brewery of Messrs. BASS and Co., in which he found—

Carbonate of lime,	9·93
Sulphate of lime,	54·40
Chloride of calcium,	13·28
Sulphate of magnesia,	0·83
	78·44

All the water used at Burton for brewing is spring water, and not that of the river Trent, as has been erroneously supposed.

On boiling, it deposits a large amount of carbonates of lime and magnesia, besides a small quantity of sulphate of lime; a little iron, which it contains, becomes also eliminated.

The geological formation from which this water appears to emanate, is New Red Sandstone; in the immediate vicinity of Burton there are large strata of new red marl, with a considerable amount of gypsum.

The water employed at the brewery of Messrs. TETLEY and SON, Leeds, bears some analogy to the preceding, as will be seen on referring to the annexed analysis by the Editor:—

	Per gallon.	
Carbonate of lime, Carbonate of magnesia,	19·78	grains.
Carbonate of the protoxide of iron,	0·93	"
Sulphate of lime,	4·97	"
Sulphate of soda,	13·09	"
Sulphate of magnesia,	9·73	"
Chloride of sodium,	7·11	"
Chloride of magnesium,	4·74	"
Loss,	1·72	"
	62·07	

The three waters contain a varying amount of carbonic acid in the uncombined state, keeping the carbonates in solution.

From the above the Editor would suggest, that when brewers in certain districts are compelled to use soft water, or that which runs off moors or fens, for want of better, they should impregnate them at second hand with gypsum, or with such limestones as are easily procurable. This plan has been found most serviceable, and the ale obtained from such artificial water has nearly equalled the renowned product of Burton.

HOPS.—The wort, as prepared from malt, is unpalatable and viscous; and to bring it into a potable state, and insure the permanence of its virtues, it has been found necessary to make some addition to it previous to fermentation. This effect is best produced by means of *hops*, the properties of which, and the characteristics by which they may be selected, will now be concisely pointed out.

Hops are the strobiles or catkins of *humulus lupulus*, a diœcious plant belonging to the natural order Urticaceæ, the culture of which was first introduced into England from Flanders in the reign of HENRY VIII.

The various parts of the hop are, scales, nuts, and lupulinic grains or glands. The scales are the enlarged and persistent bracts enclosing the nuts, which are small, hard, nearly globular, and covered with aromatic superficial glands, commonly termed *yellow powder* or *lupulin*. These form the most important part of the strobiles.

Dry hops ought to yield about one-sixth of these grains. They are usually mingled with sand.

PEREIRA says they are rounded, of a cellular texture, golden-yellow colored, somewhat transparent, and are sessile, or nearly so.

The common centre around which the cells are arranged has been denominated the *hilum*. They lose their spherical form by exsiccation, and, when placed in water, give out an immense number of minute globules. Under different circumstances they become ruptured, allowing an inner envelope to escape. TURPIN states that they consist of two vesicles, one eviscerating the other, the interior containing *globules*, *aromatic oil*, and *a gas*, and affirms that, in the bubbles of disengaged gas, a large number of crystals are formed.

The scales and lupulinic grains have been analyzed by PAYEN, CHEVALLIER, and PELLETAN, with the following results:—

LUPULINIC GRAINS.

	Centesimally represented.
Volatile oil,	2·00
Bitter principle—lupulin,	10·30
Resin,	55·00
Lignin,	32·00
Fatty, astringent, and gummy matters, osmazom, malic and carbonic acids, salts, as malate of lime, acetate of ammonia, chloride of potassium, sulphate of potassa, *et cetera*,	traces.
Loss,	·70
	100·00

The scales were found to consist of astringent matter, inert coloring matter, chlorophyl, gum, lignin, and salts of potassa, lime, and ammonia, containing acetic, hydrochloric, sulphuric, nitric, and other acids.

The scales usually have lupulinic matter adhering, from which it is almost impossible to free them.

Dr. IVES also examined the lupulinic grains, and obtained—

	Centesimally represented.
Tannin,	4·16
Extractive,	8·33
Bitter principle,	9·16
Wax,	10·00
Resin,	30·00
Lignin,	38·33
Loss,	·02
	100·00

The volatile oil exists in the lupulinic grains, and is procured by distilling them or the hops with water. It has a yellowish color, an acrid taste, and its odor is similar to that of the strobiles. It is partially soluble in water, but more so in alcohol and ether. It has a specific gravity of 0·910, becomes resinified by keeping, and is said to have a narcotic influence on the system. The water which distils over with the oil contains acetate of ammonia.

Dr. RUDOLPH WAGNER has lately published an interesting paper upon the oil of hops, and as his results are different from all hitherto obtained, a notice of them may be serviceable to the brewer. Dr. WAGNER distilled the oil from fresh hops with water. It constituted about eight per cent. of the air-dried flowers. It possessed a clear brownish-yellow color, and had a strong odor of hops, and a slightly bitter taste analogous to thyme. Its specific gravity was 0·908 at 61° Fahr. It scarcely reddened litmus paper, and was very sparingly soluble in water, requiring more than six hundred times its weight for solution. *It contained no sulphur.* The oil, rendered anhydrous by distillation over fused chloride of calcium, partly evaporates at a temperature below the boiling point of water. It begins to boil at 257°, rising to 347°, where it remains stationary for some time, and at which temperature nearly one-sixth of the clear oil distils over. The portion passing over between 347° and 437°, and constituting one-half of the oil, was also very clear, and had the odor of the crude oil. That which passed over between 437° and 455° was of a yellow color. The residue in the retort, about one-sixth of the quantity submitted to distillation, was brownish, and like turpentine. It is, therefore, evident that oil of hops is a mixture of oils. The crude oil does not give, with ammonia-silver, a metallic mirror. It is therefore not an aldehyde. When mixed with alcohol-potassa, it becomes brown, and when distilled affords alcohol, and an oil having the odor of rosemary.

After the greatest part of the oil and spirit has distilled over, a violent action takes place, hydrogen is evolved, and carbonate of potassa, mixed with a potassa salt of a volatile fatty acid, remains: the latter, when decomposed with diluted sulphuric acid, evolves an odor indicating the presence of caprylic and pelargonic acids.

From PAYEN and CHEVALLIER'S analyses and report, the oil was supposed to resemble oils of mustard, asafœtida, *et cetera*, and to belong to the ethereal oils *containing sulphur; that it dissolved largely in water*, and on this account preserved the beer, and that it acted partly as the narcotic in beer and hops.

According to WAGNER the oil is isomeric with Borneo camphor, oils of cajeput and bergamot, and with the aldehyde of campholic acid. This chemist, in conjunction with Dr. BIBRA, made experiments upon animals, to ascertain whether the oil of hops acted as a narcotic; *they found it had no such action.*

The bitter principle of hops, or lupulin, may be obtained by treating the aqueous extract of lupulinic grains, combined with a little lime, with alcohol. The solution thus formed is to be evaporated, the mass treated with water, and the solution again boiled to dryness. The residue, on washing with ether, is lupulin. It is uncrystallizable, white, very bitter, soluble in twenty parts of water, very soluble in alcohol, and in ether slightly so. The aqueous solution froths on agitation, and, according to PEREIRA, gives no precipitate with tincture of galls or acetate of lead. Lupulin contains no nitrogen. It is devoid of the narcotic properties of the oil, and is said to have caused loss of appetite, and diminished digestive power, when administered in small doses.

The tannin serves, in brewing, to precipitate the nitrogenized or albuminous matter of the barley, and, therefore, assists clarification.

The resin has a golden-yellow color, becomes orange-yellow on exposure to the air, dissolves both in alcohol and ether, and is apparently the oil changed by oxidation.

A decoction of hops feebly reddens litmus, owing to free acid being present; sulphuric and tannic acids, and also lime, may be detected in it even by those who have little experience in analysis.

Dr. IVES first applied the term lupulin to the pollen, or, as it is technically denominated, *the condition* of the hop; the name has been applied since, however, to the bitter extract of the scales.

The Editor found that hops, in the usual marketable state, lose between eleven and twelve per cent when dried at 212° Fahr., and leave, on burning, from five to eight per cent. of ash.

Mr. HOLDEN obtained, on incinerating a good sample of hops, 7·708 per cent. of inorganic residue.

The drying of the hop constitutes a very important part of its management; it is performed in kilns, generally of very unscientific construction, and apparently capable of great improvement.

In Sussex, these are termed *oast-houses*. The heat imparted by the fire in drying is of great importance, and should in no instance exceed 119° or 120° Fahr.

The farina or pollen which falls through the hair-cloth, or wire, in the course of desiccation, is a valuable article, and is denominated *hop-dust*. If care is taken that no particles of fire fall into the kiln-pit, and the hop-dust be frequently removed therefrom, so as to insure its freedom from extraneous matter, it is scarcely less useful to the brewer than hops themselves. One pound of the dust is equal to four times the quantity of the strobiles. In dark-colored or common beer, a small amount might always be used without injury.

According to BRANDE, in order to give the hops a good color, they are subjected to fumigation with sulphurous acid; after this process they are packed into sacks or *pockets*, and subjected to great pressure, so as to prevent access of air, and their consequent deterioration.

Qualities.—The medicinal properties of hops are numerous. The odorous emanations arising from them possess marked narcotic properties. Hence a pillow of the cones has often been prescribed to promote sleep, in cases where the administration of opium could not be effected, or would have been objectionable. Both infusion and tincture of hops are mild and agreeable aromatic tonics. They sometimes manifest diuretic, or, when the skin is kept warm, sudorific qualities. Their sedative, soporific, and anodyne properties are very uncertain.

The lupulinic grains are aromatic and tonic, and appear to be soothing, tranquillizing, and slightly sedative and soporific. Hops have been given internally to relieve restlessness consequent upon exhaustion or fatigue, to induce sleep in the wakefulness of mania and other maladies, to calm nervous irritation, and to relieve pain in gout and rheumatism. They have also been applied, topically, in the form of a fomentation or poultice, as a resolvent or discutient in painful swellings or tumors.—*Pereira.*

The Editor does not attach much importance to the assertion that hops are narcotic, and that their influence upon the system is wonderful, especially when they are used in pillows, as he considers that the imagination plays a most important part in all such matters, —*vide* spirit-rapping, table-turning, *et cetera.*

The properties of hops in brewing are important, but may be given in few words.

All the medical qualities are to some degree exerted by the liquors in which they have been employed. They render the beer more stimulant and cordial, and the bitter principle overcomes the disagreeable sweetness arising from the malt, and which, if unneutralized, might be offensive, if not injurious, to persons having weak digestive organs.

The stimulating and strengthening qualities found in bitter beer, may be said to be owing almost entirely to the hops.

They are slightly anti-fermentive, and but for the use of them in brewing, the ale produced would soon undergo the acetous fermentation, or, in popular language, become sour.

Selection.—The flavor of the Golding or Farnham hops is rich and delicate, but the plant is one of the most tender cultivated, and the crop is uncertain. They are the heaviest, consequently possessing the greatest amount of farina or condition, and the flower is the most diminutive.

The Flemish plant produces a large flower, often three inches in length, and is considered as one of the most hardy kinds. It is productive, but of light weight, and is ill flavored.

In the districts of Kent and Sussex, the Canterbury grape, a very good and useful hop in the trade, is much cultivated.

Other varieties are produced in various parts of the country, especially in a district called North Clay, in Nottinghamshire. These hops are strong, and fit only for porter brewing, even when mellowed by age. An extract from TIZARD as to the various estimates of the value of each variety may not be unacceptable.

Farnhams, he states, are in high repute, though not worth the price the brewer usually gives for them, unless the proximity of his residence be a consideration in their favor. The North Clays are rankest in taste, and fetch a better price with a certain class of buyers than those from Kent, though not generally so high as the Farnham variety. Those grown in the neighborhood of Canterbury have been much prized for their superiority, but that is not invariable. The produce of the county of Kent, though pre-eminent both for strength and flavor, differs according to soil and season, which are not always adapted to each other. The Wealds are celebrated in some of the Southern and Midland counties, but in those more north, as Cheshire and Lancashire, the Worcesters are preferred for their mildness, and for the grateful sensation they yield; some use a few Sussex or Kents with them, but most brewers in the counties just referred to, reject the growth of Kent as unpleasing to their customers.

But, however good the produce of any district may be in general, it must not be supposed that there are no bad samples of those varieties.

Such bags should be chosen as are heaviest, because it is the farina which gives weight, and hops which lose a part of it from fine weather or over-ripeness, in picking or turning on the oast, will considerably diminish in gravity.

They should feel clammy when handled, should be uniform in color, without greenish particles in the flower, and full of hard seeds, and farina or condition.

Mould may be discovered in the sample by the strig of the flower being partly bare of leaf. Particular attention must also be paid to crust, proceeding from damp or bad keeping, as it injures the quality more than age.

From the uncertainty of the seasons, the hop is an article liable to considerable fluctuations in its commercial value. The duty upon hops is twopence per pound, with five per cent. additional; this levy does not extend to Ireland. Latterly, foreign hops have been used to a considerable extent by many brewers, even in the manufacture of the finest ales; they do not, however, possess that richness of flavor so characteristic of the English growth, and hence they are never used alone, but mixed with English hops in different proportions, varying from a third to a sixth of the latter. This mixture is found to answer in a manner as well as if the entire were of home growth, especially where bitterness is required to a considerable extent, and only a moderate portion of the flavor.

The foreign hops imported into Great Britain in 1852 were 34,622 pounds, whilst in 1853 the quantity amounted to 4,739,307 pounds.

The following table shows the number of pounds weight of hops which paid duty in England during the years 1848 to 1853, inclusive, the amount of duty levied thereon, and the number of acres of land under crop, during each of these years:—

Year.	Acres.	Pounds of hops.	Amount of duty.		
1848	49,232	44,343,984	£388,007	3	8
1849	42,798	16,650,914	145,693	4	9
1850	43,125	48,537,669	424,702	3	0
1851	43,242	27,042,919	236,623	1	10
1852	46,157	51,102,494	447,144	8	1¾
1853	49,367	31,751,693	277,824	16	9

BREWING.—After the foregoing details, the main subject to which they refer will now be entered upon, namely, *brewing*, and to make the matter as clear and intelligible to the reader as possible, the treatise will be divided into several heads, corresponding with the various sections of the work, as actually performed in the manufactory. These are *grinding* and *mashing; boiling*, *hopping*, and *cooling*; *fermenting*, *cleansing*, *fining*, and *storing;* in addition to which, the particular methods for making other kinds of malt beverages, besides the ales most generally consumed, will be pointed out and discussed.

It may be mentioned at the outset, that grinding, mashing, and fermenting have been referred to at some length under Alcohol and the manufacture of whisky, at page 58, *et seq.*, and therefore a full explanation of these operations will in some degree be unnecessary; but as they are performed in a manner somewhat dissimilar in this case, in conformity with a particular purpose, it will be requisite to notice them as far as they affect the preparation of beer.

GRINDING.—Little, however, need be said on grinding, in addition to what has been already advanced; but were any one thing to be particularized more than another, it would be the necessity of having the natural cohesiveness of the grain destroyed in such a way, that the water may have free access to every particle of it, to insure the entire extraction of the valuable constituents. Of the various methods resorted to, whether by reducing the grain between stones in the ordinary way, or by steel mills, wherein it is cut or torn in the same manner as coffee is ground, or by crushing between rollers, that mode is preferable which disintegrates the grain completely, and loosens the husk from the fleshy parts without separating the two. A moment's consideration will show that these conditions are not fulfilled by either of the first two methods; and it is only from the use of rollers that the malt can be expected to make the nearest approach to the criterion mentioned. A secondary but important advantage is gained, by having the grain completely broken up though still adhering together; namely, the facility with which the mash is racked off, leaving only little of the extract in the grains. When it is ground fine, the matter, besides being apt to *set* and form a mucilaginous magma, retains much of the liquor, which cannot be removed except by long washing, thus rendering the worts dilute, and exposing them to the danger of acetification in the succeeding treatment. When the particles of the grains still adhere, though their natural texture is broken, each shell forms, as it were, a filter, through which the clear liquor percolates readily, leaving any matter, which might be taken up mechanically, behind. If the grain be torn or sliced, as by the metal mills, in which the available matter remains to some extent adhering to the husk in its natural state, considerable loss will be sustained, for the water will not penetrate these parts during the period usually allowed for mashing. That this is the case, is evident from the well-known fact, that dried malt will float on water for a period of twenty-four hours, without absorbing as much of the menstruum as would increase its gravity sufficiently to cause it to sink.

The annexed cuts—Figs. 156, 157—represent, in front and lateral section, the cylinder malt mill. I is a sloping trough, through which the malt passes from its bin or floor to the hopper, A, whence it is shaken between the iron rollers, B, D, working at their extremities in bearers or sockets of hard brass, fitted securely into the side frames, which are also of iron. E is a screw passing through the upright, and serving to force the bearer of one roller towards that of the other, so as to bring them nearer together when the malt is wanted in a finer state of division. G is the square end of the axis, by which one of the rollers is turned. The other rotates by means of a pair of equal-toothed wheels, H, fitted to the opposite extremities of the axes of the cylinders. *d* is a catch working into the teeth of a ratchet wheel, not shown in the engraving, on the end of the rollers. The lever, *c*, comes in contact with the trough, *b*, at the bottom of the hopper, giving it a shaking motion, which discharges the malt upon the rollers from the side sluice, *a*. *e e* are scraper-plates, the edges of which, pressing on the rollers, remove adhering matter, and thus keep them clean.

Fig. 156.

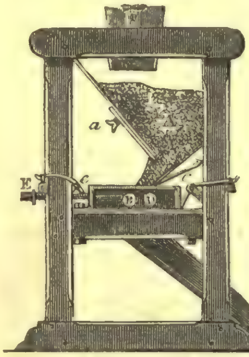
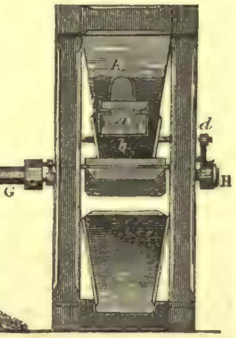


Fig. 157



When rollers are used they should be of equal size, and move with the same degree of velocity, otherwise the proper and looked-for quality will not be found in the crushed malt. Another important feature is, that the grain ought to be screened or passed through a wire sieve before it falls between the crushers, for the purpose of removing any pebbles, lest they should come against the rollers and injure them. As great inconvenience and loss may be suffered from imperfect grinding, the chief care of the brewer ought to be directed to the erection of such machinery in every department as will efficiently answer all his requirements. After the grinding, the malt is usually conducted by an endless chain of buckets to a proper receptacle placed over the mash-tub, where it remains till required.

MASHING.—To the brewer this is a subject of vital importance, and, as stated under ALCOHOL, opinions regarding its proper management are as various and as fickle among a great number as are the colors of the chameleon. These individuals generally pride themselves with the thought of having ascertained, or industriously gathered facts, bearing upon the regulation of the time, temperature, or proportion of the materials in the mash, which give them an advantage over their neighbor, and they cling with an absurd tenacity to the idea, and conduct all their operations accordingly, notwithstanding that the inutility of their mode may at once be demonstrated by a few moments' enlightened consideration. By knowing the leading properties of the materials, and their behavior with other bodies at various degrees of temperature, and the like, nothing more is required to attain perfection in the mashing, than to apportion these in a judicious and reasonable manner. An almost universal foible, if such it might be called, which influences the manufacturer is the idea, that if his methods of working were known to his brethren of the same trade, it would contribute very much to his ruin; although it will be found, upon examination, that very little difference exists between *his* particular working and that pursued by hosts of others. It generally happens that valuable discoveries result from disinterested research, or are hit upon by many at the same period, and then become in some measure generalized; but as to a manufacturer keeping any process of real worth clandestine, in order to appropriate the fruits of his study and genius, supposing it really possesses any worth, it almost invariably occurs, in the event of his doing so, that disappointment awaits him. Experiments are readily performed now-a-days, and the mind is peculiarly active in drawing deductions from known facts, which contribute to simplify the complexity of many operations; and hence it follows, that the various improvements which have taken place in every branch of art, not grounded on or corroborated by these ordeals, are seldom worthy of notice.

Wherever there is a real progression or discovery, the peculiar provision of the laws is such that it can be communicated to the world, or at least as far as the dominion of Britain extends, with greater benefit than disadvantage to the propounder, whilst, at the same time, the public derives a portion of the good arising from it, and is enlightened at comparatively trifling expense. Knowledge is disseminated in this way in a hundredfold degree, and at a fraction of the cost which would attend it if privacy and concealment were studied at every step; and the good which has arisen to society in consequence is incalculable, for instances are not wanting to show that many persons who never thought of becoming serviceable in the way of advancing art and science, upon seeing commonplace and well-known facts brought to accomplish great results, have arisen from a lethargic inactivity to strike out, as it were, by new-born talents hitherto latent, great and valuable discoveries.

Almost innumerable instances are recorded which corroborate the truth of what is here asserted, and the principle is so well understood in a purely scientific light, that the numerous books daily printed are fraught with original matter of one kind or other, which, supposing that it does not always extend to the elucidation of the topics in all their ramifications, yet what has been communicated opens the way for succeeding research, that arrives at the discovery of the object originally sought, or, by a happy digression, to that of other more valuable and interesting ends. BACON well conceived the value of being unreserved in all scientific and philosophical matters, as appears from the course he suggests; namely, that men should not be vain in publishing their knowledge, whether orally or by writing, neither should they be cunning in secreting what they have acquired, but be generous and free in communicating the facts, making them as comprehensive and as simple as possible. Were not this the directing principle, the nineteenth century would be far from possessing that enlightenment and thirst for progress manifested by all classes and grades of society, but more especially in the cycle of arts and manufactures. Looking, therefore, at the general course of things, it is evident that those who seek for knowledge with a serious and diligent spirit will not be unrewarded; the fanciful recipés of a class of ignorant men will no longer be coveted; and, in particularly applying the facts to the art of brewing, every person possessing a discriminating sense, a moderate practice in the execution of the mechanical part of his business, and a chemical manual, wherein he may learn the fundamental properties and changes which his materials possess and undergo, may cast all the supposed charms which are, or may be reputed, the ultimatum of perfection, to the wind.

It is to be understood, however, that considerable difficulty stands in the way of the brewer in the large quantity of the substances upon which he works; and the dread of failure, in the course which might be suggested as an improvement, forces him to follow the old routine of business; nevertheless, if he be fully conversant with the nature and behavior of the soluble constituents of his malt, reason will place a wholesome restraint upon him from running to extremes which would be fatal, and will direct him in the intermediate course, wherein the success and security from loss are to be found. A knowledge of the materials will again be productive of the happiest results, when the ever-varying state of the atmosphere is most unpropitious; for by it he will be able to make such modifications as will effectually counteract acetification, his direst enemy, which invades him with the first rays of the summer's sun, and hovers over the building, waiting to gain an entrance at every opening which want of attention in the mashing, cooling, or fermenting of the worts, or any uncleanliness in the utensils, in the shape of albuminous or mucilaginous matter undergoing the acid phase of fermentation, might afford. Many instances could be cited, were it deemed necessary, of the complete loss of the whole of the goods at different stages of the work—some in the mashing, when, instead of a clear concentrated extract, a small quantity of a mawkish amylaceous liquid had been obtained, which readily entered into the acetous fermentation, and, instead of yielding an agreeable, grateful, and wholesome beer, nothing was found but vinegar; meanwhile the remainder of the valuable materials of the malt lay enveloped, or *locked up*, by the impenetrable folds of mucilaginous matter, caused by the application of a high temperature in the mash water. Often the infection of acidity is caught up during the cooling; sometimes the fermentation completely fails.

In speaking of the mashing, and pointing out the manner in which it is, or ought to be, conducted by the brewer, it is necessary that the reader should recur to what has been said of this operation, and the *rationale* that was given, explanatory of the changes that take place in the transformation of the starch into sugar, under Alcohol, at page 61, for the same remarks apply to the process as conducted in the brewer's tun.

There is no doubt that some improvements are yet to be effected in the extraction of malt, notwithstanding that many very specious advancements have been made in this direction, which, in a greater or less degree, have been found serviceable in increasing the quantity of matter in the wort, or protecting the goods from the destructive action of acidity.

Before stating the particular operations of mashing, it may be well to make a few allusions to the quantity of extractive matter usually obtained from malt, and the problem of its thorough exhaustion, a point which is the grand aim of mashing. From the analyses given of malt, as well as those of barley, it will be seen that the available constituents of the former amount to 78·3 per cent. when dried by the ordinary means; and as a quarter of good malt generally weighs three hundred and fifty-two pounds, it follows that 275·5 pounds of these are available valuable matter, the remainder being water and husk. It is to be borne in mind that all this quantity is not saccharine matter, but that there exists in it a variable proportion of albumen and gluten; these, however, are abstracted to a great extent in the mashing, and are afterwards removed, as will be seen further on. Now, the best practical results average about ninety to ninety-five pounds, as shown by the barrel gravity saccharometers, per quarter; but, as every unit of this number equals 2·6, or, according to DRING and FAGE, and CASARTELLI, 2·7 pounds of real extract, it is evident that the total of the valuable ingredients is 234 to 249 pounds; for 90 × 2·6 = 234; and 95 × 2·6

= 249; but, if the calculation be made according to the latter authorities, the produce will be 243 and 256·5 pounds.

It is, however, easy for the brewer to ascertain when he is successful in his exhaustions, and also what ought to remain after fermentation to give body to his product. It will be well, also, to be able to find the amount of extract in a wort from the gravity of the liquor, as indicated by the saccharometer, without the necessity of recurring to the tables, or sliding rules accompanying them; for it frequently happens that errors creep into such calculations, and the results they point to are sometimes greater, sometimes less, than the real amount contained in the worts: to do this, all that is required is to multiply the indication by 2·6, or 2·618—2·7, according to CASARTELLI—and the product will be the real weight of extract in each barrel of the wort.

By this means the total extract per quarter in the first mash may be found, and, by deducting it from 275·5, the remainder is what is left in the grains to be extracted in the next mash; knowing this, the liquor employed may be regulated accordingly, so as to obtain a dense wort, and thereby avoid the danger of acetification, to which dilute worts expose the products. In addition to these advantages, the director has the great satisfaction of performing his work methodically, and as one who is master of his business.

As to the nature of the change that takes place in the mash-tun, and the circumstances which induce it, enough has been said upon this point under Acetic acid and Alcohol to throw light upon the metamorphosis of the starch, and other bodies of an analogous composition, into sugar, as will be found, it is expected, sufficiently explicit to satisfy the desire of every brewer; but as acetic acid and alcohol are of a different nature from the article now considered, so the modification of those principles, although their ultimate effects are the same in the three instances, requires in this case special discussion.

It is the object of the vinegar-maker to obtain a wort of such strength, or containing as much saccharine matter, as will give a product affording, after the fermentation and oxidation of the alcohol, about five per cent. of acetic acid,—of the distiller to extract the valuable principles entirely, and produce a menstruum which subsequently will completely ferment, leaving as little of the saccharum as possible latent in the liquor; but the brewer's course is different from these, inasmuch as *he* wishes a dense extract, not to acetify, nor, at the same time, to be wholly converted into alcohol, but to preserve it from the former, and restrict the latter to such a degree as will merely cause the formation of sufficient spirit to communicate a pleasant hilarity to those partaking of it, reserving the greater portion of the goods for communicating to it richness, unctuousness, and flavor; and if he leaves these particulars, or any one of them, unattended to, his beverage will very quickly be distasteful to his customers.

From these differences in the operations of the three classes of manufacturers, whose art borders upon the same principle—that of the exhaustion of the malt and the conversion of the extractive matters into sugar—it will be plain to every one, that there must be a marked difference between the course followed by each; the peculiarities of the brewer's methods will therefore engage attention for the present.

The first important point with the brewer is the complete abstraction of the saccharine and amylaceous substances in his malt; and next to this, but not less important, is, that he is to effect it with the smallest possible quantity of liquor, it being understood that he must be rigorously careful to prevent any acidification. Six or seven barrels of water per quarter of malt are generally sufficient for the exhaustion; of which two and a quarter to three and a quarter barrels are lost in the after operations of boiling and fermenting before the products are of good quality. The manner of applying the liquid seems to have an important bearing upon the result, as is evident from the very great proportion which is proved to be useless, by being expelled afterwards in different stages of the manufacture.

Now, the question naturally suggests itself—Why is this liquor employed in the mashing in the first instance? and then, Can the great waste be obviated, and the expense incurred by the brewer in supplying fuel and other necessaries in order to concentrate his worts, be saved?

The Editor thinks that much requires to be attended to in this particular; and it appears so practicable, that it is surprising it should have been overlooked by those brewers and chemists who have treated the subject, while they continue to instruct in the old method. It is plain that the diastase and gluten of the malt are capable of transforming a much larger quantity of starch into sugar than what is present, and it is no less obvious that the water employed is sufficient to hold in solution a far greater proportion of the saccharine substance than it can possibly meet with in any brewing operation; it therefore follows that the methods adopted are defective, inasmuch as an unnecessarily large quantity of fluid is used to attain the results, which, according to the known properties of the constituents, might be accomplished with less. Some steps have already been taken in this direction by Mr. TIZARD, in introducing an improved mode of mashing by means of his attemperator, and also in his treatment of the hops; nevertheless, it seems that a great deal has yet to be accomplished before the brewer can arrive at that perfection in his art which is so very desirable. It is well known that the diastase of the malt is most active when the liquid is rather dilute, and the temperature is between 160° and 170° Fahr.; but as the latter might be injurious at the outset in a brewing operation, the former, and even 165°, could be supplied with safety. Hence it is apparent, that by sustaining an equalized temperature, and with the use of a moderately large quantity of water, the conversion of the starch into glucose will be complete, and that it can be almost entirely extracted in the first solution, leaving nothing in the first mash for the subsequent sparging, but to wash out that portion imbibed by the grains. By accomplishing this with four to five barrels, instead of six to seven, the brewer would derive material advantage, as the *lengths* which are at present employed, and subsequently expelled by evaporation, *et cetera*—a process that entails a loss of time and money—would to a great extent be unnecessary. Another inducement to the adoption of means for obtaining dense worts, is one which brewers must necessarily value, namely, the production of sound beer; for it is impossible to brew a good beverage from an inferior wort; and, when the latter is weak, the tendency to acetification is far greater than if a heavy extract were operated upon.

Considerations like these ought to be sufficient for those whose practice it is to vary, in almost every case, the manner of mashing, now applying a low temperature, then a high one, but always using repeated mashings, which entail the trouble of continued boiling afterwards, and ultimately impair the quality of their goods.

The chief point is to apply as much water, and maintain such an initial temperature, as will, on sufficient time being allowed, completely disintegrate the grains at one mashing, and leave nothing for the subsequent abstractions but what remains of the first in their pores. This is the highest perfection in mashing, and whatever may be adduced by bookmakers and particular persons, upon modifications of working, and the application of high or low degrees of temperature, it would be well if the intelligent brewer would study how far such instructions are likely to operate in favor of the criterion here laid down before he embraces them.

Having spoken of the principles of mashing as fully as the subject requires, the usual routine of the process will now be entered upon.

The first great point to be attained in a brewery is, scrupulous cleanliness, particularly in the various vessels, lest any albuminous or amylaceous substances should be left adhering to them, and which, by entering into a putrescent fermentation, would communicate the same to the worts, and prove highly detrimental. It is hoped that the importance of this requirement is so well understood, that it will be unnecessary to dwell further upon it; still, its being overlooked would ruin an establishment, even if every other particular were carefully attended to, and managed with consummate skill and ability. The only means of securing this point are to wash the various backs, boilers, coolers, and other utensils, occasionally with lime-water, made by macerating a bushel of quicklime in about twenty barrels of water—otherwise to have all the utensils made of metal; it would be desirable, also, to retain any backs, or other vessels which may not be constantly in use, full of water, till such time as they are needed. The manager should be likewise careful to keep the mash-tun perfectly clean; for if any grains should remain in it after a previous brewing, their albuminous contents might suffer decomposition, and give rise to, or induce, an acid fermentation, which, if absorbed, would prove destructive in the succeeding brewing. Too much precaution cannot be used in guarding against these causes of mischief, which, though apparently trifling in themselves, operate so as to render the brewer liable to a heavy loss, by giving rise to those ruinous decompositions to which allusion has been made.

Unless the brewer mashes every day, it would be well that he should make all the preliminaries required for the proper execution of his task on the day of brewing; the coppers should be charged with liquor, and fuel sufficient to sustain the fire for heating the materials should be provided; where the mashing is performed daily, these requirements are secured as a matter of course.

The work, on the day of brewing, should be vigorously proceeded with as early as possible, and especially in hot weather, which demands on the part of the operator greater vigilance and care to secure his success.

It is customary to have a journal, wherein the temperature of the atmosphere, the quantity of malt, the heats of the different mashings, as well as of the tap, and other particulars, are recorded; and this, besides being always necessary, to show the business habits of the foreman, very often leads to some improvements, when several operations are afterwards studiously considered and their results compared.

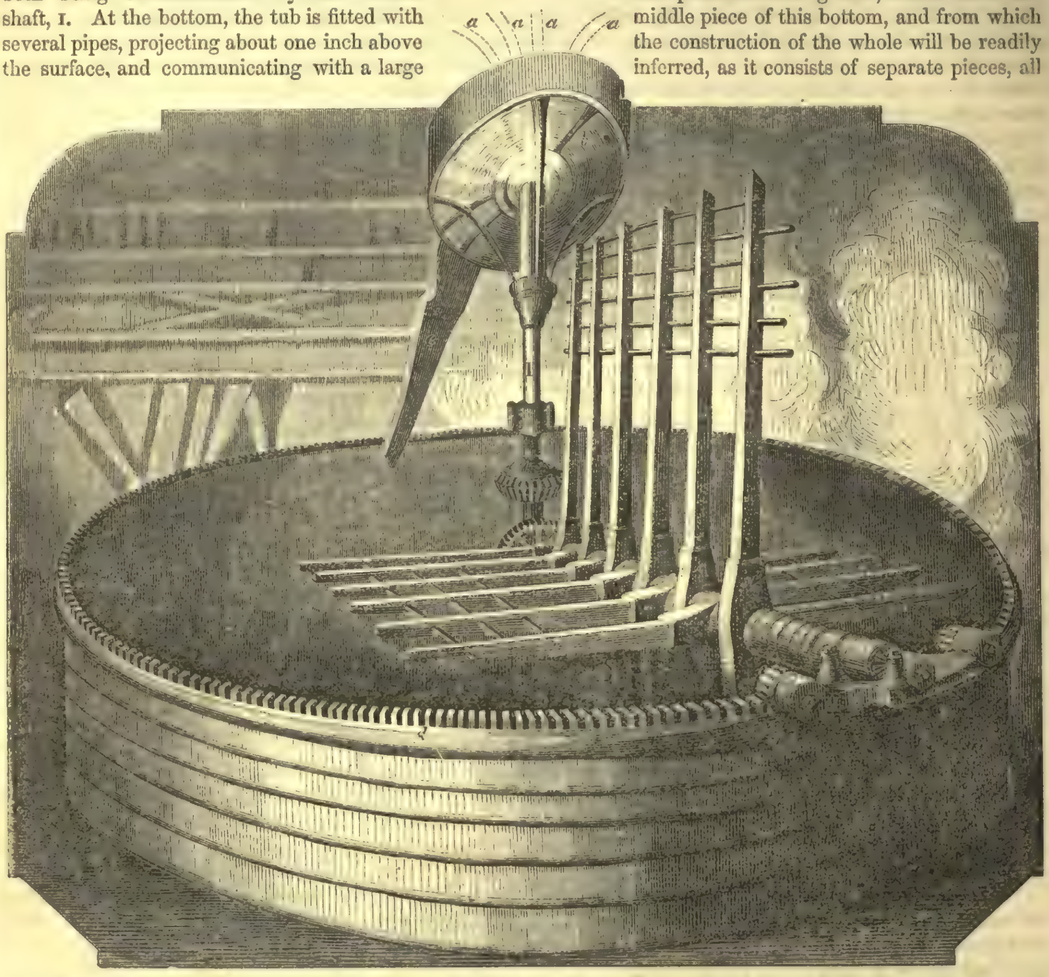
The malt, of whatever description it may be, should be ground, if possible, the day previous to mashing, or, at most, it should not be retained longer than three or four days crushed before it is submitted to the mash-tun; for, if kept a long time, it will attract moisture from the atmosphere, become heated, through the effects of an internal decomposition of the saccharine substance, and render the beverage of a bad quality.

The ground malt is usually conducted, in well-regulated breweries, by an Archimedean screw to the hoppers over the tun in the mashing-room, which serve as magazines for it, and whence it is let into the latter, when fit, and macerated with water. There are two modes of accomplishing this mixture—one by manual labor, and the other by machinery; but the latter is preferable on all occasions, as it is much more effectual in breaking up the masses of malt which are apt to form in the water. Indeed, very often serious injuries arise from the *balling* of the malt, when the mashing has been carelessly performed with oars, or too large a quantity of water has been run upon it at first; for, besides being wasted, by enveloping a certain volume of air, and being but partially wetted, and surrounded by an elevated temperature, the agglomerated portions very quickly generate acetic acid, if not timely prevented, by being broken up with proper machinery.

The mash-tun and its appendages, which are always subjects of importance in the brewery, will here be described. The illustration presented is copied from the large tun in use at Messrs. ALLSOPP and SONS, of Burton-on-Trent, and by Dr. BÖTTINGER kindly supplied to the Editor.

Fig. 158 represents this tun fitted up with very ingenious and effective machinery for mixing the malt and water thoroughly. The hopper, to which reference has been already made, is not seen in the drawing, but it is placed on strong wooden bearers immediately above the mash-tun, and is connected by four shoots, *a*, to the so-called feeder, *b*, which is elongated into a narrow trunk, *c*. The tub itself has the enormous dimensions of twenty-one feet diameter, and is six feet deep; it is mounted with a toothed rail, *d*, into which the cogs of a small wheel, *f*, at the end of the stirring or mashing apparatus, *g*, fit; this mashing machine consists of a strong iron shaft, to which a number of wooden rakes is attached; it has a double motion, one upon its axis, and the other round the tun, both being communicated by the central shaft, I. At the bottom, the tub is fitted with several pipes, projecting about one inch above the surface, and communicating with a large one below; they serve to conduct the liquor to the under-back or receiving vessel. Above this bottom is the filtering or straining apparatus, consisting of a false bottom of wood, perforated with a large number of minute holes, countersunk in the lower side, as represented in Fig. 159, which shows the middle piece of this bottom, and from which the construction of the whole will be readily inferred, as it consists of separate pieces, all closely fitting together, and supported by bearers, which raise the false about two inches above the true bottom.

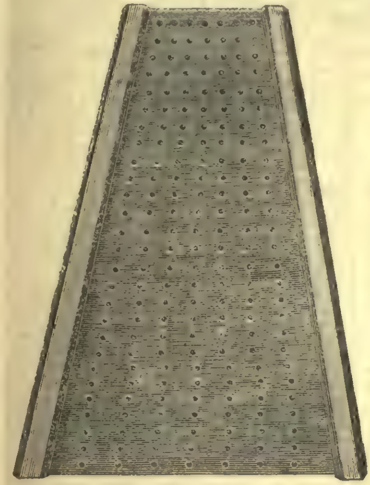
Fig. 158.



On mashing, the water, at a high temperature, is first let into the tub, and when the latter and its adjuncts have attained a moderate degree of heat, by abstracting caloric from the liquid, which reduces it to the proper mashing point, the malt is added from the hopper through the feeder; motion is then communicated to the machine, and the contents kept in brisk agitation till the mixing is completed. When this is done, the tub is carefully covered down, to preserve the heat of the mash, and exclude the air from the wort as much as possible. After about two hours' rest in this state, it is drawn off to the copper; an operation which must be performed with great care, to insure the liquor being perfectly bright, and free from any solid particles of malt. At this stage the sweet liquor is apt to enter upon the vinous fermentation, and thence to pass to the acetic, to prevent which the temperature is raised to ebullition, and the hops added; meantime the partly exhausted malt, after the whole of the liquor has been drawn, is to be subjected to a second operation. For this purpose the tub is uncovered, and a fresh quantity of water, the amount of which is regulated according to the density of the first worts, or the quantity of the matter yet unextracted, but which will be afterwards referred to, is turned on at the proper heat, and mashed by the machine, as in the foregoing instance; the tub is then covered, and the whole allowed to digest for one hour, or less, according to circumstances, and then drawn off as before. By proper attention, the whole of the requisite constituents of the malt should be taken up by these two mashings; sometimes, when the mash is very stiff, a third sparge is let in upon the grist to exhaust it, but the product is used only for *table beer*.

Having, in this short sketch of the mash-tun and its operations, given an outline of the whole course of mashing, a few remarks in explanation of the process will now be added. It will be seen that—as is the custom with a great many—the water is let into the tun at a higher degree of heat than is required by the mash, allowing it to cool down to the proper temperature before the introduction of the malt. Others, again, admit the malt and heated water simultaneously, while the machine, being put in motion, mixes them thoroughly. In the latter instance, it is plain that the heat of the liquor must be much higher than the initial heat at which the constituents of the malt should be extracted, namely 160°, or bordering upon it; for the caloric of the water is communicated to the mash-tun, as likewise to the goods, and from these causes a decrease of 20° or 30°, or more, is observed, according to the state of the weather; and it is equally obvious that the mixing of the malt and a liquor of 180° or 190°, is unadvisable; for although, in the event of mixing them, a mean temperature of 158° or 160° may result, yet the starch, albuminous, and glutinous part, cannot but be rendered insoluble in those portions with which the solution comes in contact at the commencement.

Fig. 159.



On the contrary, if the water be poured in at 170°, or under the mean, after fifteen or twenty minutes it will be far below that at which the diastase and gluten are most active in converting the starch into glucose. The conclusions from these observations evidently favor the heating of the mash-tun with the water, and when it has been reduced to 165°, or between this and 170°, to admit the malt from the hopper, and mash rapidly. In this case the malt is the only body which is to abstract the heat, and the slight elevation of the temperature supplied for meeting this decrease does not react so injuriously upon the goods as in the first case.

Others, again, turn on as much water at a low degree of heat as will moisten the malt completely, and cause it to swell, after which, the remaining quantity of water required to make up the wort is let on at 190° to 194°, and mashed in the usual way. This method is said to be advantageous—first, by lessening the tendency to set, and secondly, by giving the diastase greater scope for acting upon the starch, as the per centage of sugar is dissolved out in the first wetting, and the residual portion is more permeable to the solution, which, having about 165° as its mean, is very effective in exhausting the goods.

It should be remembered, however, that diastase is very soluble, and that it is wholly, or to a great extent, removed with the sugar, leaving only the gluten in proximity with the starch to effect its solution. During the subsequent part of the operation, when the water of a higher temperature is poured on, many authorities of long experience affirm that the particles of this active principle are placed at such a distance from the starch, that the diastase cannot exert the same influence as if it and the starch were exhausted at the same time. The quantity of water which is usually taken, varies from one and a half to two and a half barrels per quarter of grist for the first mash, according to the system of working followed by particular persons; but if the mean temperature could be sustained throughout the mashing, it is quite evident that one barrel, six firkins, which weighs about 630 pounds, would be even more than sufficient to exhaust the quarter of malt of its soluble ingredients, consisting principally of glucose or saccharine matter, which requires only 1·33 parts of water in the cold for its solution, but much less will suffice when the temperature is raised as in mashing.

From all these peculiarities, it seems that the general defect of mashing lies either in not extracting the whole of the goods, in consequence of the gluten and portions of the starch of the grain forming a gelatinous mass which envelopes the starch and sugar, and does not allow the water to flow off in consequence of too elevated a temperature; or the starch may indeed be carried off in suspension, but owing to the low temperature it is not converted into glucose, and in the subsequent operations this kind of wort is prone to acidify and spoil, particularly if the time of mashing and tapping be long. It is evident that the maintenance of a due degree of heat, and the employment of the proper amount of liquid so as to have a dense wort, are the two chief points which must arrest the brewer's attention; and if he could surmount all the difficulties arising from long custom, based upon imperfectly understood principles, and make the attempt to add science to his working practice, it is evident that a considerable part, if not all the loss which is at present so generally sustained by brewers, might be converted into profit. The usual method of mashing, by letting the water into the tun at an elevated temperature, and then the malt, or both simultaneously, so that by their admixture a medium temperature may be attained, does not answer all the requirements which are wanted, since the application and distribution of the heat is at the first glance partial and unequal; besides, it readily passes off by radiation and conduction, leaving the mash at such a temperature as cannot exert the desirable influence upon the conversion of starch into sugar. The only contrivance worthy of notice, which has been introduced for the purpose of obviating this disadvantage, is that patented by Mr. Tizard of London, and known as the *mashing attemperator*. This apparatus serves the double purpose of masher and attemperator at the same time, and there is no doubt that it is productive of the good effects which it professes to accomplish, since it can be so managed to preserve the heat at any temperature which may be deemed most suitable, and for an indefinite time, should it be required. The heating medium is completely under the control of the operator, and therefore he can urge or restrain it within certain limits, even to a nicety.

The influence of the attemperator, in communicating a temperature of 160° to 165° Fahr. to the goods during the mashing, is highly beneficial, inasmuch as the whole of the starch is saccharified, and most probably a portion of the mucilage which is formed during the malting. Hence its great advantage at once appears palpable; and, consequently, deserving of the brewer's attention. In the absence of the attemperator, the best course for the ordinary brewer is to use only as much liquor as will moisten the malt, and then apply the remainder so as to maintain the heat of the mash at 160° or 165° during the mashing.

The time usually devoted to this operation has been mentioned, at page 252, as being two hours after the water has been thoroughly incorporated with the malt, which generally happens in about twenty minutes, when the quantity of malt is small; when a large bulk of goods is operated upon, the mashing takes from a half to one hour, but this is not the case with a great many brewers. The following table relating to the temperature and time of the standing of the mash, *et cetera*, is taken from LEVESQUE, and throws considerable light on this point. It should be remarked, however, that the heat of the mash-water varies according to the malt employed, that for pale malt being the lowest, whilst for high-colored it may be poured on at a much more elevated temperature.

Temperature of the air at mashing.	CLASS I. Heat of the mash 146° to 148°.	Time of standing of the mash.	Temperature of the air at mashing.	CLASS II. Heat of the mash 145° to 147°.		Time of standing of the mash.	Temperature of the air at mashing.	CLASS III Heat of the mash 144° to 146°.		Time of standing of the mash.	Temperature of the air at mashing.	CLASS IV. Heat of the mash 143° to 145°.		Time of standing of the mash.
	Firkins per quarter 6.			Firkins per quarter 7.	Firkins per quarter 8.			Firkins per quarter 9.	Firkins per quarter 10.			Firkins per quarter 11.	Firkins per quarter 12.	
		h. m.				h. m.				h. m.				h. m.
10°	197·00	4·00	10°	189·00	184·00	3·00	10°	178·00	175·00	2·00	10°	172·00	170·00	1·00
15	195·17	4·00	15	187·42	182·59	3·00	15	176·84	173·92	2·00	15	171·00	169·19	1·00
20	193·34	4·00	20	185·84	181·18	3·00	20	175·68	172·84	2·00	20	170·00	168·28	1·00
25	191·51	4·00	25	184·26	179·77	3·00	25	174·52	171·76	2·00	25	169·00	167·37	1·00
30	189·68	4·00	30	182·68	178·36	3·00	30	173·36	170·68	2·00	30	168·00	166·46	1·00
35	187·85	4·00	35	180·10	176·95	3·00	35	172·20	169·60	2·00	35	167·00	165·55	1·00
40	186·02	4·00	40	179·52	175·54	3·00	40	171·04	168·52	2·00	40	166·00	164·64	1·00
45	184·19	4·00	45	177·94	174·13	3·00	45	169·88	167·44	2·00	45	165·00	163·73	1·00
50	182·36	4·00	50	176·36	172·72	3·00	50	168·72	166·36	2·00	50	164·00	162·82	1·00
55	180·53	4·00	55	174·78	171·31	3·00	55	167·56	165·28	2·00	55	163·00	161·91	1·00
60	178·70	3·40	60	173·20	169·90	2·45	60	166·40	164·20	1·50	60	162·00	161·10	0·55
65	176·87	3·20	65	171·62	168·49	2·30	65	165·24	163·12	1·40	65	161·00	160·19	0·50
70	175·04	3·00	70	170·04	167·07	2·15	70	164·08	162·04	1·30	70	160·00	159·28	0·45
Heat of the tap from 144° to 146°.			Heat of the tap from 143° to 145°.				Heat of the tap from 142° to 144°.				Heat of the tap from 141° to 143°.			

In the first column under each class of this table, the temperature of the atmosphere at the time of mashing is noted; the next columns are the degrees at which the water should stand to bring the mash to the points at the head of the columns, and the figures at the foot specify the temperature at which the tap stands.

Mashing in this way often causes much variation in the results, owing to the dryness or particular quality of the malt, and the state of the atmosphere. When very dry malt is used, on mixing it with water of a certain heat, the resulting temperature is not an arithmetical mean of the two, but is somewhat higher, owing to an elevation of a few degrees, caused by the conversion of starch into sugar, and its solution in water; for invariably chemical decompositions and combinations give rise to heat, and this fact should be kept in mind when adding the water for the mash, and its temperature regulated accordingly. As an example of the first, the action of sulphuric acid on alcohol might be cited, and of the second instance, the effect produced when this acid is added to water; in both cases, considerable elevation of heat is indicated. Were there no development of heat, the temperature would be under the mean of the substances, in consequence of the amount of caloric which the malt takes up, without giving the same indication by the thermometer as water under a like influence; it happens, however, that, when mixed, there is a rise which, when working upon a small scale, is not very material, but if a large body of goods be operated upon, so as to retain the heat, this elevation is considerable; and if not carefully observed, or the original points proportioned thereto, it may be the cause of setting the goods, and of much loss and injury.

When barley is mixed with twice its volume of water, the heat arising from this mixture will be about the mean temperature; but if pale malt be similarly treated, the result will exceed the mean; and if highly dried brown malt be taken, the thermometer will indicate a rise of 40° over the mean: this elevation always takes place in the first mash, during which the conversion of the starch proceeds with the greatest activity. Such results do not, however, always attend the mixing of the water and malt, as, when the latter has stood some time after grinding, it absorbs water from the atmosphere and becomes *mellowed*, in which case the development of the heat is not so great as when the goods are perfectly dry; hence, when mashing such mellowed malt, the liquor ought to be somewhat hotter than is used with the fresh.

Another circumstance which influences the heat of the mash is the bulk of materials taken; thus, it is evident that the temperature, when only two barrels of water per quarter are employed, must be higher than if three were taken, notwithstanding that the rise by mixing is greater in the first instance; both give off an equal amount of caloric to the tun; but as in the latter instance there is more of the substance, it contains more heat collectively than the former, and therefore it is not reduced so much by the abstraction.

DONOVAN, speaking of the temperature to be employed in mashing, lays down the following as a general rule:—For well-dried pale malt, provided the atmosphere does not exceed 50° Fahr., the heat of the first mash-water may be, but should never exceed, 170°; that of the second, 180°; and for the third, 185°, but never beyond.

It may be observed that the danger of acetification of dense worts at a temperature of 160° Fahr., is not incurred by a slight prolongation of the time of mashing and setting, as might be at first apprehended, for both are unfavorable to the change; this will be clearly seen on referring to the article on ACETIC ACID and VINEGAR, at page 7. Now, if the agitation of the goods by the machine be continued only for a short time, from half an hour to an hour, the question might be asked, will the conversion of the starch be completed during that time? Again, during the subsidence of the grains and other matters distributed through the liquor by the mashing, will the whole of the starch become saccharified? The answers to these questions might with truth be in the negative; and the conclusion forces itself upon the reader, that the shortness of the time of mashing, and the ineffectual methods adopted for maintaining a suitable temperature, are the chief causes which operate *against* the obtaining of dense worts, and in favor of acetification. This is evident to every brewer who takes the trouble to examine the subject rationally: allowing that the mashing is successful in discharging the whole of the starch and other valuable matters from the grain, and that nothing is left in the shell—which, however, is not so—on the suspension of the motion of the machine the chief part of the starch remains, as is well known, unacted upon; and as the grains fall to the bottom, they carry considerable portions of the goods with them out of the reach of the solution, and the increased gravity of the liquors, in consequence of the portion of glucose that is formed, also precipitates and hastens the descent of the yet unconverted starch, leaving in a short time the upper part of the liquid clear, and of a very low density. Certainly, the quantity of wort imbibed by the grains assists in the change into sugar, but the transformation is not nearly so effectual as if the contents were disseminated through the bulk of liquid taken for the mash. Another consideration which tends to show that the prolonging of the mash, provided the due degree of heat is kept up, as by **TIZARD**'s attemperator, would not cause the time of *setting the tap* to extend beyond the usual period allowed in the generality of breweries, is, that the chief part of the starch being saccharified whilst the liquid is in agitation, the time afterwards necessary for the clearing of the wort would not be so long as in the present instance; for the grains, the sinking of which is to be effected, being dense and in large masses, would readily subside, and the delay caused by the minute particles of starch still floating in the liquor towards the bottom would be avoided. These strictures may appear to the brewer at variance with his preconceived views; still the Editor feels assured that, by due care, the course which he recommends would prove effectual, since the principle on which it is based is conformable to the well-known law which regulates the solution of matter.

Having thus far spoken of the data and principles that ought to regulate mashing at this stage of the process—for the first mash is the most important—the method of drawing off the wort, or *setting the tap*, as it is called, together with the extraction of the portion of the goods still retained in the grains by the operation of sparging, or after-mashing, will next be considered.

In reference to the setting of the tap, **LEVESQUE** very justly remarks that the goods should be drawn off at the same degree as is indicated at the conclusion of the mashing, and recommends the adoption of the plan without incurring any risk of hurtful decompositions taking place, whatever the variety of malt worked upon. Those who may not be very conversant with the real nature of the subject, and may have doubts as to the quality of the malt—its newness, hardness, weight, slackness, or dryness, all of which require a variation of the heat, or of the quantity of liquor—if they are already acquainted with the final heat of the first mash of a good operation, they have only to raise the tap to this point, and copy it in their subsequent mashings.

From the great necessity which exists of governing the heat of liquids, it is evident that the thermometer must come into general request, as, by its use, acidity, arising from a low, and setting from an excessive heat, may be entirely prevented.

The thermometers of the usual make, with or without a case and reservoir, offer some difficulty in this respect; because, as **TIZARD** asserts, when the case and reservoir are affixed, the progressive heat of the mash is conveyed too slowly to be of accurate use; and on the other hand, with an exposed bulb, the mercury drops so instantaneously on its removal from the mash, and with such rapidity, especially at high temperatures, that before the grains can be wiped off the scale, and the vision of the operator has penetrated the cloud of steam, and the film of mucilaginous or other matters adhering to the glass which intervenes, the slender column of mercury cannot be discerned till it will have fallen many degrees below the real heat of the mash. Apart from these great inconveniences, there is also the probability of the instrument being broken by the action of the machine. At best, the mere dipping of a thermometer into the goods is so unsatisfactory, and so hazardous in its applications, that its indication might lead to the setting of the whole mash. To remedy these obstacles, **TIZARD** attaches to the back of his attemperating machine two movable brackets, reaching midway between the centre and side of the mash-tun, the extremities of which are provided with sockets. Into these sockets a long thermometer is dropped, having a scale which stands above the surface of the mash, and a little lamp attached. In this way the instrument travels with the machine, and the index, from being illuminated, will show truthfully the heat of the mash, and any variation as it occurs. Similar contrivances might be adopted in brewing with the ordinary mashing machines, at little expense; and it is needless to say that the guarantee which would thus be given for knowing the exact temperature, would, when compared with the system usually resorted to, be of incalculable service.

The first mash being completed, and the under-back wherein the sweet worts are received being thoroughly clean, the tap is turned on gently at first, and afterwards more quickly, till the liquor runs half bore. Unless great care be exercised, the worts will not flow off bright and clear as they should do, and particles of the more finely divided grain, which are sometimes productive of inconvenience in the succeeding operations, will percolate.

If the process has been successful, the wort will be of the same shade of color as the malt employed; it should have a tough and close head of a silvery whiteness, and passing, when examined in the vessel, to a delicate cream on the surface, full, effervescing, and fine flavored, considerably more so than the succeeding extract, in consequence of the more mucilaginous and resinous parts of the grist not being abstracted. When the heat of the mash is too high, it is observed that the silvery white head has a tinge of brown, and this color will be deeper in proportion to the greater elevation of the mash above the proper degree. Again, if the heat be low, the characteristics of the head do not appear, neither is it so close, firm, bright, or lively in flavor. In very low heats the head will not stand, but fly off instantly, and the taps will be thick and muddy; this kind of wort, on being exposed to the air, will readily enter into decomposition and turn acid.

When the whole of the extract has been drained off, the quantity of liquor to be used in removing the residuary portion, retained mechanically by the grist, as well as any starch which may still be present, is turned on, and if the preceding details be attended to, the quantity of the starch will be found to be very inconsiderable. Many persons employ from three-eighths to one-half the quantity of water taken from the first extract, and add it at 185°, or 10° over that at which the first mash is made, and treat the goods similarly to what was done at the commencement, except that the time extends only to a quarter or one-half that granted to the first. The same precautions should be observed in setting the tap as have been already mentioned, and the worts conveyed to the boiler with the first portion.

By an economical disposal of the temperature and duration of the mash, as well as the proportion of the liquor taken, the residual starch in the grains will be inappreciable; but when, as in many cases, the operations are conducted in an uncouth, unscientific, and often in an irrational way, there remains after the second mash as much as from eight to ten pounds per barrel extract, and it even happens that it is not wholly removed by the third watering. This product, however, is coarse and ill-flavored, owing to the great proportion of bitter resin and mucilage intermixed with it, and which hitherto remained in the grains, the temperature not being retained at that degree at which the diastase and gluten could exert their combined influence in saccharizing these substances. In order to avoid the accumulation of such degenerating constituents in the third and fourth mash, the opinion of LEVESQUE is, that the heat should be 10° to 12° higher in the second than in the first mash, if products are run into the boiler as the strong wort; if three mashings are to be made for the same, he says a difference of 5° or 6° in each is most suitable, making the final one at 160°.

It will be observed, that all these customs of mashing so repeatedly are at variance with the principles inculcated by the Editor, and which he believes to be just in all their details, and certain to result in success, if a little exertion were made on the part of the operator; it is also his opinion, that when the activity of diastase and gluten is maintained during the mashing by contact with the constituents at the proper degree of heat, considerable portions of the gum or mucilage are transformed into sugar; and hence their presence would not be found to such an extent in the final sparging as when the old process is followed. In a scientific point of view, the conversion of gum into glucose is an ascertained fact; and the method of accomplishing this conversion differs in nothing from the course adopted on the Continent for manufacturing sugar from starch—namely, boiling with very dilute sulphuric acid. On the same grounds, the catalytic action of diastase and gluten should, theoretically, transform the mucilage, or gum of the malt, into grape sugar as effectually as it does the starch; for these two substances are of analogous composition, and maintain that analogy with grape sugar, as will be observed from the annexed formulæ, showing the composition of the three bodies:—

Gum, anhydrous,..................	$C_{12}\,H_{11}\,O_{11}$
Starch, anhydrous,.................	$C_{12}\,H_{10}\,O_{10}$
Grape sugar, anhydrous,...........	$C_{12}\,H_{12}\,O_{12}$
Grape sugar, hydrated,............	$C_{12}\,H_{14}\,O_{14}$

From this it is plain that the only difference in the elementary composition of the three substances is, that gum contains one, and anhydrous grape sugar two equivalents of water more than the starch, and that the change of the other two into sugar involves no greater complexity of action than the assimilation of a few equivalents of hydrogen and oxygen; but, in doing this, the whole atomic constituents may arrange themselves differently, though still retaining the relative elementary proportion to the other constituents existing in either starch or gum.

Before leaving this subject, it may be stated as certain, that the change of the gum into saccharum is much less active than that of the starch, and hence it requires the proximity of the saccharifying agent in the malt, and the intervention of a continued heat at the proper pitch, before it is completed. From this circumstance arises the great value of Mr. TIZARD'S apparatus, as it maintains the contents of the mash tun at the most efficient degree of heat throughout the mashing.

There is another method followed for abstracting the residuary matters in the grist, after the first mash is completed, which is called *sparging*, from the circumstance that the liquid is sprinkled on the goods from numerous outlets. It is said to be very beneficial in its results, particularly when the whole of the wort is intended for the strong or the better quality of beer. The method of sparging is as follows:—When the tap has been set for drawing off the first wort, the hot liquor, of the same temperature as the preceding mash, is sprinkled on from a machine constructed thus: a perforated tube is taken and laid upon a bar, the whole being placed horizontally in the tun, and rested upon a pin in the centre, and over which a receiving vessel is placed to supply the tube with water. The perforations extend to the whole length of the two or three arms of the tube, so that the liquid flows out horizontally, but in opposite directions; and through the effect of the force of this efflux, together with the centrifugal motion communicated by the current coming from the receiving vessel, the pipe is kept rotating, and the liquor is dispersed equally over the goods. Some, instead of the tube, use a cover, which they place over the liquor, and direct the stream upon it; the first method seems, however, to be more efficient.

Many persons do not set the sparger till one-fourth, one-half, or even three-fourths, of the strong extract is drawn off; but when the liquid is sprinkled on gently—as it must be from the perforated tubes—there need be no apprehension of the wort being diluted; and the good which it does, by displacing the quantity of the stronger mash imbibed by the malt, as also by exhausting the grist of the residual saccharum, without taking up the resinous constituents, is an undoubted recommendation; besides, when the chief part of the first mash is drawn off before the sparging, the grains accumulate in a denser layer on the bottom, and the facility with which it is desirable that the edulcoration should penetrate every portion of the grist, cannot be turned to advantage. The mashing attemperator already alluded to, has perforated tubes attached to it, so that water can be transmitted through them over the mash.

To those whose routine of working is based on old established practice, this mode may appear ruinous, as their after mashings contain six to ten pounds of extract per barrel, which are calculated to be as valuable as an equal proportion of the first wort; but, without stopping to inquire whether this is the case or not, it may be sufficient to assert, on the grounds which it is hoped have been clearly explained in the foregoing, that, if a proper course of mashing be adopted, there will be none of this matter—the whole of the valuable constituent will be taken up in the first wort, and what remains of it embedded in the grist, removed by the washing or sparging, in the manner which has just been described. A dense and valuable wort will be thus obtained, and the subsequent concentration—as will be explained under the Boiling, in the next stage—the time expended, and the danger of decomposition, to which the extraction of weak and impure goods subjects the operator, are entirely obviated.

It is necessary to have the sparging continued without intermission, till the whole of the soluble matters is removed, using only as much liquor as is necessary to make up the proper lengths.

The grains left after mashing—see analysis, page 244—or when the whole of the starch has been removed, are very beneficial for the use of swine and cattle, as they contain gum, and some of the nitrogenous or protein constituents of the barley, in the shape of gluten, together with a certain amount of cellulose, which is valuable and as effective in nourishing as an equivalent weight of the original unmalted grain. In addition to these, if the methods recommended in the mashing have been attended to, there will be a further quantity of mucilage, which will contribute, in the animal economy, to effect the same purposes and ends as starch.

SACCHAROMETRY.—Before dwelling circumstantially on the *boiling*, *hopping*, and *cooling*, it will be desirable to make some further allusion to the methods at the brewer's command for taking the density, and for making himself acquainted with the amount of matter in his wort, as well at the high temperature at which it is drawn off from the under-back, as when he reduces it in the refrigerator. The knowledge of the gravity of the product after fermentation, so as to ascertain the quantity of spirit and saccharine matters contained in it, is of importance to every brewer.

Reference has been made, at page 250, to the means whereby the worts may be tested, and their content of saccharine matter ascertained, either from the specific gravity or by the saccharometer; but as the liquor at this stage is usually between 150° and 160° Fahr., the indication which it gives is only the apparent density, since, by expansion, the bulk of the solution is considerably increased; and, therefore, the amount of solid extractive matter, in any given volume of the liquor, is much less than what the same bulk would show at 60°, the barometer being at 29·5 or 30 inches.

The saccharometers chiefly employed are those of ALLAN, BATE, DRING and FAGE, and LONG. The first three are recommended by the Excise; but, as ALLAN'S has been discarded, the instruments of BATE, and DRING and FAGE, are solely used by the Government. BATE'S is usually made of metal, has five floats answering to the different strengths of the wort, and one to indicate which of the poises will suit on every occasion, mostly on the same plan as SYKES' alcoholometer, described at page 132. The instrument is accompanied by a book, wherein are copious explanations and directions for using it, together with sixteen pages of tables of gravity and strengths per barrel, containing over 40,000 figures, in 10,000 distinct determinations, calculated to answer every degree of specific gravity, from ·995 to 1·150, as also every alternate degree of temperature, from 50° to 150° Fahr. Notwithstanding all this labor and diversity of numbers, TIZARD says that it is scarcely possible to look down a double column of degrees and results, especially towards the right, and not discover great irregularity in the deductions.

He points this out in respect to the conclusions of the two hydrometers recommended by Government, in the quantity of extract in the gallon and barrel of wort, of the same gravity, as follows :—

Specific gravity by the saccharometer.	Quantity of solid extract in pounds.				Excisable difference in each barrel.
	In each gallon.		In each barrel.		
	Allan.	Bate.	Allan.	Bate.	
1001	0·0296	0·026	1·0656	0·936	0·119
1010	0·2997	0·258	10·7890	9·288	1·501
1015	0·4517	0·387	16·2600	13·932	2·328
1100	3·2638	2·593	117·4840	93·448	24·036
1150	5·1182	3·903	184·2540	140·508	43·746

The wide discrepancy of these results speaks loudly against Allan's, assuming that Bate is right; but the forementioned gentleman is far from this opinion, and justly so, if it be considered that the expansion of the volume of liquor, by the increased saccharine extract, is *regular*, and in an *even ratio;* for, instead of the results being so many multiples of the factor laid down for the gravity 1001, it will be observed that they are considerably under, without the content in any way accounting for it.

The instrument of Dring and Fage is more simple than the foregoing, as it has but two weights, corresponding to worts containing twenty and forty pounds per barrel. It is constructed of brass, and is similar in shape to a glass hydrometer, except that the stem whereon the indices are engraved is square, and marked on three sides: the first, from 1 to 20; the second, from 20 to 40; and the third, from 40 to 60. No weight need be used till the wort exceeds twenty pounds per barrel; after this, the weight No. 1 is slipped on at the top, and the indications observed on the side of the stem, marked No. 2, till the figure 40 is exposed, and lastly, the weight No. 2 is placed on, and the value sought on the side marked No. 3, till it reaches 60, which is the limit of the instrument.

Mr. Long, of London, is the maker of another saccharometer, said to be very exact, but which is not recognized by the Government; it has one accompanying poise, to be used when the wort exceeds twenty-five pounds per barrel. This instrument is based and regulated on the assumption, that a wort marking twenty pounds per barrel on the instrument, contains fifty-two pounds of real extract; and, taking the weight of a gallon of such saccharine matter to be 1625, water being 1000, the preceding quantity occupies 3·2 gallons, leaving 32·8 as the space occupied by the water, and hence the volume, or decimal part of a gallon, filled by each pound, is 0·6154. Dispensing with the rigid accuracy which analytical chemistry teaches, and viewing these results in a commercial and business-like manner, where truth and despatch, without very scrupulous exactness, are the requirements, the conclusions of Long are worthy of being received, as they lead to the estimation of the saccharum with some degree of certainty.

Tizard, by a series of calculations upon the same basis as those of Long, arrived at results somewhat different, and which are tabulated by him, as annexed, showing, by comparison, the discrepancy between them and the numbers given by the makers of the most popular instruments :—

Specific gravity.	Weight of solid extract to the imperial gallon.				
	Allan.	Dring and Fage.	Bate.	Long.	Tizard.
1010	0·2997	0·2777	0·258	0·2583	0·2618
1020	0·6053	0·5555	0·516	0·5194	0·5236
1030	0·9168	0·8333	0·775	0·7777	0·7854
1040	1·2343	1·1111	1·033	1·0388	1·0472
1050	1·5577	1·3888	1·293	1·3000	1·3090
1060	1·8870	1·6666	1·552	1·5583	1·5708
1070	2·2223	1·9444	1·812	1·8194	1·8326
1080	2·5634	2·2222	2·071	2·0777	2·0944
1090	2·9105	2·5000	2·332	2·3388	2·3562
1100	3·2636	2·7777	2·593	2·6000	2·6180
1110	3·6226	3·0555	2·854	2·8583	2·8798
1120	3·9875	3·3333	3·116	3·1194	3·1416
1130	4·3584	3·6111	3·378	3·3777	3·4034
1140	4·7352	3·8888	3·640	3·6388	3·6652
1150	5·1182	4·1666	3·903	3·9000	3·9270

It may be remarked that the products of Tizard are higher than those of Bate and Long; their being multiples of the factor ·2618 may be easily seen to have resulted from the circumstance that they are calculations, whereas in the other statements, if experiments were resorted to, to corroborate calculations, the inequalities might have arisen from various relative causes; by their aid, however, the quantity of extract in a wort may be pretty accurately ascertained, and when the brewer knows theoretically what he is to expect, and is, besides, able to make the calculation, without blindly trusting to tables, provided he multiplies the gravity indicated by the saccharometer into ·2618, the product will be the pounds of saccharum per barrel.

Dr. Ure, who in 1830 experimented on this subject, states that the specific gravity of the solid dry extract of malt is 1·264, and the specific volume 0·7911, that is, ten pounds of it will occupy the volume of 7·911 of water. When this extract is dissolved in its own weight of water, the density of the resulting liquid, by calculation, ought to be 1·1166, whereas, by experiment, it proved to be 1·216, thus showing that a considerable condensation of volume had taken place in the act of combination with the water.

The following table, showing the relation between the specific gravity of the solutions of malt extract and the quantity of matter they contain, illustrates the above :—

Malt extract. Water.	Malt extract in 100.	Sugar in 100.	Specific gravity.
600 + 600	50·00	47·00	1·2160
600 + 900	40·00	37·00	1·1670
600 + 1200	33·33	31·50	1·1350
600 + 1500	28·57	26·75	1·1130
600 + 1800	25·00	24·00	1·1000

Regarding the saccharometric tables constructed by Bate and others on solutions of sugar, and not upon those of extract of malt, Ure remarks that they agree pretty well with the former, but differ materially from the latter; Allan's tables, he says, give the amount of a certain form of solid saccharine matter extracted from malt, and dried at 175° Fahr.; but he found it impossible to make a solid extract of solutions of malt, except at much higher temperatures; further, he asserts that the extract upon which Allan operated was by no means dry; for at 1·100 gravity, he assigns 29·669 per cent. of solid matter, whereas only twenty-five per cent. is present; and again, at 1·135 per cent., he states 40, when it is only 33·33.

Apart from the foregoing consideration, there is another important circumstance which must be taken into account in ascertaining the gravity—namely, the different expansions of bodies at various degrees of temperature, from 32° to their boiling point. When many liquids are heated from 32°, or their point of greatest density, to 212°, considerable difference is observed in this respect; for instance, the dilatation of alcohol is much greater than that of water, and this again than mercury, and so of numerous other liquids. The amount of expansion of different liquids in passing through 180°, that is, from 32° to 212° Fahrenheit, is found by experiment to be—

Alcohol, ...	$\frac{1}{9}$	Oil of turpentine, ...	$\frac{1}{14}$
Nitric acid, ...	$\frac{1}{9}$	Sulphuric acid,..........	$\frac{1}{17}$
Fixed oils, ...	$\frac{1}{12}$	Water,.....................	$\frac{1}{23}$
Ether,.......................	$\frac{1}{14}$	Mercury,..................	$\frac{1}{55}$

It may be well to illustrate the meaning of the above, by showing the difference in volume of water from 32° to 212°, as given by several chemists who have investigated the subject.

There is one remark, however, which is deserving of being made, for the sake of those who may not be conversant with such subjects—namely, that heat communicated to the bottom of liquids is readily diffused through the whole body; not, however, by radiation, as is the case with solids, but by the dilatation of the inferior particles, which renders them specifically lighter than those above them, on which account they ascend, their place being occupied by other globules; these, again, receiving warmth and ascending like the preceding. Thus, by the constant exposure of fresh portions of water to heat, and the motion produced in the liquor by their rarefaction, the whole bulk is brought to that degree beyond which any application of more heat would destroy the limits within which the density and liquidity remain, and the fluid would become aeriform. It is plain, then, that it is gravitation which exerts such great influence on the transmission of caloric through a body of liquid, as well from the facts above cited, as from its tardy absorption by the solution when the heat is applied to its surface, in which case the supernatant particles only receive the rays by which they are rendered lighter and continue to float upon the denser. This slowness of acquiring heat from the surface led **RUMFORD** to deny that water, or fluids generally, had any power of conducting it; still it is long since known that liquids do conduct heat, though in a ratio far inferior to solids.

Science has converted this phenomenon to highly beneficial uses in many departments of industrial progress. The thermometer, with all its inestimable benefits, is based upon it, and at the present day, the application of expanding substances to the requirements of manufactures, trade, and navigation, commands no small consideration in contributing to the wealth of nations.

According to **KOPP**, water expands when heated from 32° to 212°, 0·042986 of its volume, as will be seen from the annexed table of the expansion of water from the freezing to the boiling temperature, the volume at 0° C., or 32° Fahr., being taken as unity:—

Temp. Cent.	Temp. Fahr.	Volume.	Temp. Cent.	Temp. Fahr.	Volume.
0°	32°	1·000000	21°	69·8°	1·001776
1	33·8	0·999947	22	71·6	1·001995
2	35·6	0·999908	23	73·4	1·002225
3	37·4	0·999885	24	75·2	1·002465
4	39·2	0·999877	25	77·0	1·002715
5	41·0	0·999883	30	86·0	1·004064
6	42·8	0·999903	35	95·0	1·005697
7	44·6	0·999938	40	104	1·007531
8	46·4	0·999986	45	113	1·009541
9	48·2	1·000048	50	122	1·011766
10	50·0	1·000124	55	131	1·014100
11	51·8	1·000213	60	140	1·016590
12	53·6	1·000314	65	149	1·019302
13	55·4	1·000429	70	158	1·022246
14	57·2	1·000556	75	167	1·025440
15	59·0	1·000695	80	176	1·028581
16	60·8	1·000846	85	185	1·031894
17	62·6	1·001010	90	194	1·035397
18	64·4	1·001184	95	203	1·039094
19	66·2	1·001370	100	212	1·042986
20	68·0	1·001567			

The preceding table shows the degree of contraction which water undergoes when heated from 32° to its point of greatest density, which is stated as 39·2° Fahr. From this point to the normal temperature of 60°, the expansion of a volume of water is 0·000894, and from this to 158°, ·021475 of its original volume. Now, a given bulk of liquid, having solid bodies, such as mineral salts, *et cetera*, dissolved in it, does not increase or contract in the same proportion when heated from 32° to 212°, as pure water, in consequence of the solid matter not being so expansible as the liquid, and hence it follows that dense worts will not dilate or contract as much as those which are more dilute. On examining worts of high temperatures, the object is to find the increase of weight consequent upon the contraction of any given bulk of liquid, when cooled from a higher to a lower degree of heat.

According to **BATE'S** tables, the allowance which should be made for every ten degrees between the normal points, 60° and 150°, is as follows:—

Saccharometric gravity.	70°	80°	90°	100°	110°	120°	130°	140°	150°	Sum.
10	1·0	1·2	1·5	1·7	1·9	2·1	2·3	2·5	2·8	17·0
50	1·2	1·4	1·6	1·8	2·1	2·3	2·5	2·7	3·0	18·6
100	1·4	1·6	1·8	2·0	2·2	2·5	2·7	2·9	3·2	20·3
150	1·6	1·8	2·0	2·2	2·4	2·7	2·9	3·2	3·4	22·2

The subjoined table, selected from those of **BATE** by **TIZARD**, will answer the purposes of the ordinary brewer; and where the corresponding degree does not occur, a correct fraction may be attached at an average, founded on the following facts. When a liquid, the specific gravity of which is 1000 at 60°, is heated to 78°, the instrument will sink two divisions below the true gravity as found at 60°, and if the temperature be elevated to 93°, it will sink four divisions, and so on; in other words, any liquid heated to these points, and tested with the hydrometer or saccharometer, will manifest a much higher density when cooled down to 60° Fahr.; thus, if there be three liquids at the temperatures of 124°, 92°, and 78°, and the instrument be dropped into them, it will sink in the first ten, in the second eight, and in the third six divisions, lower than it would in the same were they cooled down to 60°; hence, when testing the liquors heated to these degrees, it is necessary to add the numbers ten, eight, six, *et cetera*, to the apparent densities, in order to find the real gravity at the standard of 60° Fahr.

Specific gravity at 60° Fahr.	Apparent gravities giving the same density at the accompanying heats as the first column at 60°.									
	Ap gr.	Degrees.	Ap. gr.	Degrees.	Ap. gr.	Degrees.	Ap. gr.	Degrees.	Ap. gr.	Degrees.
1000	998	79·00°	996	93·00°	994	105·00°	992	115·50°	990	125·20°
1010	1008	78·00	1006	92·00	1004	104·00	1002	114·50	1000	124·00
1020	1018	78·00	1016	91·33	1014	103·00	1012	113·50	1010	122·80
1030	1028	77·33	1026	90·66	1024	102·50	1022	112·50	1020	122·00
1040	1038	76·66	1036	90·00	1034	101·50	1032	111·50	1030	120·80
1050	1048	76·00	1046	89·33	1044	100·66	1042	111·00	1040	120·00
1060	1058	76·00	1056	88·66	1054	100·00	1052	110·00	1050	118·80
1070	1068	75·33	1066	88·00	1064	99·00	1062	109·00	1060	118·00
1080	1078	74·66	1076	87·33	1074	98·00	1072	108·00	1070	116·80
1090	1088	74·66	1086	86·66	1084	97·50	1082	107·00	1080	116·00
1100	1098	74·00	1096	86·00	1094	96·50	1092	106·50	1090	114·80
1110	1108	74·00	1106	85·50	1104	96·00	1102	105·50	1100	114·00
1120	1118	73·50	1116	85·00	1114	95·50	1112	104·50	1110	113·20
1130	1128	73·33	1126	84·50	1124	94·50	1122	104·00	1120	112·40
1140	1138	73·00	1136	84·00	1134	94·00	1132	103·20	1130	111·40
1150	1148	72·66	1146	83·50	1144	93·50	1142	104·40	1140	110·80

The following theorem, for reducing the gravities of hot worts, is taken from TIZARD *on brewing*:—To unity, or 1, representing the par or standard of water, add 0·1 for every twenty-five points of gravity indicated by the instrument, and 0·01 for each degree of temperature above 60, and multiply the sum by ten times the latter number for the correction.

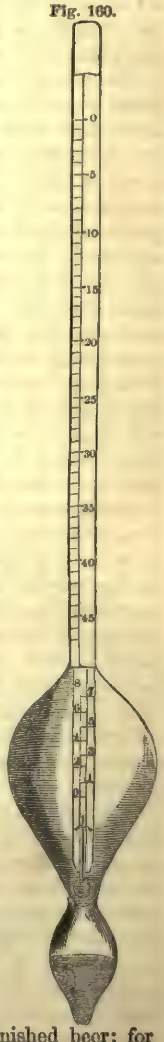
Example 1.—Let the apparent density be 6, and the temperature 92°, then $(1 + {\cdot}32) \times 3{\cdot}2 = 4{\cdot}224$, which, added to the original 6, gives 10·224.

Example 2.—Apparent gravity 27, temperature 124°.

Here $(1{\cdot}1 + {\cdot}64) \times 6{\cdot}4 = 1{\cdot}74 \times 6{\cdot}4 = 11{\cdot}136$, and $11{\cdot}136 + 27 = 38{\cdot}136$, results which agree with those of BATE.

Before leaving this subject, it may be well to notice a new saccharometer, constructed by Mr. J. CASARTELLI, of Liverpool and Manchester, on the principle of that of DRING and FAGE. It is made of glass, of the shape of the ordinary hydrometer, as sketched in the annexed—Fig. 160—except that in the large bulb a small thermometer is placed to register the temperature of the liquor. The stem of the saccharometer is graduated by a scale from 0 to 55, denoting so many pounds per barrel of extractive matter, and the plate affixed to the thermometer is engraved with figures 0 to 8, the former corresponding to 60°, and the latter to 157° Fahr., each of which represents one division of the stem, as the liquor at these respective temperatures would, if cooled to 60°, exactly mark an extra degree to what it shows. The manner of using it is as follows:—Having floated it till the level of the liquor is stationary, the indication is noted; the instrument is then taken out, and the figure to which the mercury has risen in the small thermometer observed and added to the preceding; the total will be the number of pounds of extractive matter in a barrel of the wort or gyle at 60°. This ingenious contrivance, besides being as correct as the instruments of DRING and FAGE, is much more simple, so that there is no need of sliding rules and thermometers, as furnished with other instruments. On the whole it is much preferable to those of metal, and although it is more fragile, yet it is not liable to lead to the wrong results which the others are apt to produce when disfigured by dinges, *et cetera*. The factor used in the instrument is 2·72, and the proportion of alcohol which the wort would yield on being fermented, is tabulated in a card accompanying it.

Fig. 160.



BOILING THE WORTS.—In order to show the chemistry of this operation, the first consideration is the composition of the worts, when drawn off from the mash-tun to the underback, and the manner in which they are affected by the boiling.

Firstly, then, from the views and detailed facts given under the mashing, it will be seen that the wort is composed of water, saccharum or glucose, mucilage or gum, generated by the heat applied in drying the malt, and some small quantities of starch, albumen, and gluten. According to the greater or less care bestowed on the preceding operations of malting and mashing, the wort will vary in its content of saccharine extract. If a wort be evaporated at a moderately elevated temperature without approaching ebullition, and the residue heated in a water or air bath, or in vacuo over sulphuric acid, to expel the last trace of moisture, every hundred parts of the dry substance will yield generally from ninety-two to ninety-four per cent. of sugar, four of gum and a bitter resinous matter, and two of albumen, gluten, and inorganic salts. The composition, however, must vary much, according to the mode adopted in the making of the malt. Most of these matters, except the sugar, may well be dispensed with in the finished beer; for they injure, rather than improve, the quality of the product.

The gluten is insoluble in water; but, in consequence of the presence of glucose and diastase—to the latter of which it in some measure assimilates in transforming the starch into sugar—it is dissolved in the mashing. The gum is soluble in the wort, as is also the albumen, excepting at a temperature approaching ebullition, when it coagulates into clots or flakes; this substance is also insoluble in alcohol, which precipitates it from its solutions.

It has been observed that the gluten of the malt, during the mashing, undergoes a change, by which lactic acid is to some extent formed. The cause of this alteration—which is rather injurious to brewing, owing to acetic acid very often resulting—is found in an incipient fermentation, whereby the casein of the crude gluten is transformed into lactic acid and other peculiar products, which change is also communicated to a portion of the starch. Boiling of the worts is avowedly practised with the intent of removing the excess of nitrogenous matter; for, if this were permitted to remain, it would undergo the putrid fermentation, and completely destroy the whole product; boiling is reputed also to give to the liquor a grateful flavor, and render it more wholesome; but the most satisfactory recommendations in its favor are, that it diminishes the liability to *acescency*, by expelling the contained air; and those matters that are subject to change, being in a measure excluded from the atmosphere, which is absolutely necessary for acetification taking place, the liquor remains sound for a long time. Boiling is resorted to for other purposes—namely, the expulsion of the excess of liquor used in the mashing, as well as for the transformation of any starch which might still remain intact into saccharum or dextrin. Attention to the principles of mashing, and the use of the attemperator, would do away with these disadvantages. There is another important object for which the worts are boiled, namely, the extraction of the valuable and medicinal principles of the hops, whereby the flavor of the liquor is improved, as well by the agreeableness of the volatile oil of the flowers, as by the bitter resin and tannin, which are dissolved out, and which destroy the luscious sickly taste of the saccharum of the worts. Besides, hops impart not only a bitter aromatic taste, but also a keeping quality, as they counteract the natural tendency of the beer to become acerb; an effect partly attributable to the precipitation of the albumen and starch by their resin and tannic acid, and partly to the antifermentable properties of their lupulin and other constituents.

Various opinions have been set forth regarding the necessity, the efficacy, and the injuriousness of boiling; generally speaking, the idea is, that from the manner in which it is usually conducted, it acts prejudicially, inasmuch as by it the most prized material of the hops—the odoriferous oil—is dissipated, and too much of the disagreeable principle and tannin extracted, whereby the bitterness and astringency become too powerful. Those who condemn boiling altogether should study its antiputrescent effects, especially where albuminous and other substances, such as casein, fibrin, *et cetera*, analogous to those in the extract, are present. Boiling has the effect of expelling air from the interstices of the particles of the liquid, and coagulating the albumen; and, by keeping the matter excluded from air or oxygen, it may be preserved without undergoing putrefaction. It is well known that nitrogenous substances, which are otherwise very readily decomposed into products of putrefaction, may be retained for a considerable period in a wholesome state, by expelling air, and keeping them afterwards in exhausted receivers. Cold effects the same thing, notwithstanding that the contact of the air is permitted; but then the main condition which induces the chemical combination of the elements of the body with the oxygen —namely, an elevated temperature—is wanting. By abstracting the air contained in the wort, and guarding against its reabsorption by keeping the liquor in exhausted vessels, it may be preserved during any length of time without giving rise to acid products, or by retaining it at a low degree of cold, its purity is not affected; but, upon the application of a heat ranging from 70° to 90°, with exposure to the influence of the air, the oxidation of the compounds present follows, and finally acetic acid, with the products usually formed in putrefying bodies, results.

Were there only saccharine matter present, the liquor might be preserved a length of time at any temperature, without danger from the acidity to which worts are so subject; but the proneness of the nitrogenous impurities to *eremacausis*, opens the way for the mucilage and sugar to pass partly into the lactic, and partly into the vinous fermentation, and then, by a further state of chemical decomposition, into acetic acid, and, it is needless to say, the whole materials are spoiled.

Thus far, in reference to the keeping of the worts, and their protection from decomposition, by boiling; its immediate effect will now be taken into account.

Evidently this operation tends to, or has for its object, the removal of albumen and any other matters which, if permitted to remain in the wort, would readily absorb oxygen on being left in contact with the air, and cause the chemical changes which brewers have so much reason to apprehend; but, in effecting this purpose, it is argued that, besides a valuable portion of the saccharum being abstracted, the essential oil of the malt is almost entirely volatilized, in consequence of the long boiling at the high temperature at which this is done. That portions of the sugar are removed, or rendered unavailable to some extent, cannot be doubted; for it is well known that when vegetal extracts, and most organic compounds, some of which are as permanent in their nature as sugar, are boiled for a long time, a gelatinous substance, similar in character to woody fibre, forms in the solution at the expense of a portion of the compound, which must have suffered decomposition. Such is the case in the open copper of the brewer, especially when the air is not excluded; but as to the oil inherent in the malt being dissipated, this is a new and gratuitous supposition which has no foundation; for the oil of the grain in its natural state is not expelled at a temperature of 212°, being enveloped by the substance, and it is well known that the volatile oil, which causes so much inconvenience to the distiller in vitiating the quality of his spirit towards the end of distillation, is generated during fermentation, as will be explained afterwards.

From what has been said, it is evident, as the correct conclusion to be drawn, that were it not for the purpose of removing the nitrogenous matters, the boiling of the worts might be dispensed with. It has been urged that distillers do not boil their worts, and yet the attenuation in the succeeding fermentation becomes most complete. This must be granted; but it should be borne in mind that they immediately remove the spirit from the gross nitrogenous products by distillation, lest the latter, if permitted to remain with it, should change it into acetic acid, by regular and well-defined laws, which have been already discussed at page 4 *et seq.* It is true, also, that the generation of alcohol in the liquor during fermentation, and the protracted way in which this is carried out in some varieties of ale breweries, would, in the first instance, cause the precipitation of the albumen and mucilage; but portions of the gluten might still remain, and though its quantity might be apparently insignificant, yet, under the various effects of temperature and other causes, it would prove destructive, if not removed either during the fermentation, in the shape of yeast; or before fermentation, by boiling; or altogether excluded by a better system of mashing. In the latter instances, however, it could not be expected that the gluten would be displaced; and as the boiling does not wholly separate it, the chief effect is to be sought in the fermentation; but the hurried manner in which this is usually performed in this country, is not at all consonant with the theoretical principles which might be adduced by the chemist as calculated to guarantee success.

It is evident, however, that the boiling of the worts liberates some, though not the whole, of this albuminous body as is supposed; for the formation of yeast afterwards in the fermenting tun, is owing to the nitrogenous matters entering into combination with oxygen, derived either from the water or sugar of the liquid. Now, if the boiling were wholly discarded, it is a question whether the excess of these substances would not prove destructive to the beverage, especially if retained for any length of time, or exported to warm climates, as, from their complexity of composition, the affinity which unites the elements together cannot be so powerful as to counteract their tendency to pass into simpler and more permanent bodies.

The latest analyses of albumen lead to the empirical formula, $C_{216}N_{27}S_2H_{169}O_{68}$, besides earthy and alkaline phosphates, without which it cannot exist; but how these are arranged is unknown.

Putrefying albumen yields, among other products, sulphide of hydrogen and sulphide of ammonium.

When oxidized by sulphuric acid and peroxide of manganese, or bichromate of potassa, it yields oil of bitter almonds, benzoic acid, various aldehydes, hydrocyanic acid, cyanide of methyl, *et cetera*, besides other products not yet investigated, by the study of which its very complex construction will be unravelled.

It is well known among brewers, if not in theory at least in effect, that beers retaining much nitrogenous substances, however richly they may be hopped and otherwise carefully prepared, cannot be preserved in warm climates; neither will they retain their qualities at home when, on tapping, the air gets access to them, unless the temperature of the atmosphere be about 45° Fahr. or lower; for as soon as the air is admitted, if the temperature is above 60° or 70°, the oxidation of the gluten commences, and the heat rises in consequence; the commotion produced causes the formation of a further quantity of alcohol from the sugar, and changes the alcohol already formed into acetic acid.

Were the fermentation of the worts carried on at a low temperature, as in Bavaria, then the excess of the albuminous and other analogous bodies might be allowed to remain, without the least inconvenience in the way of causing putrefaction, so as to terminate in acetification, and there would be no need of removing any portion of them by the preparatory operation of boiling.

Many brewers allege that their only reason for boiling is the extraction of the lupulin of the hop, and to effect this the ebullition is continued at no small expense and trouble for a considerable period; but this view is not entitled to much credit, assuming the truth of the preceding remarks on the subject. Others, on the contrary, denounce boiling as being, next to acetic acid, the bane of the brewery; but reason affirms, and time and experience attest, that there is a mean which affords security from the bad effects of either extreme.

Albumen is insoluble in water at a temperature approaching ebullition, and the expansion of the air caused by the imbibition of the heat dissipates it as soon as it reaches 212° Fahr.; the further continuation of the heat after this point is gained, must evidently have in view the agglutination of the finely-divided insoluble particles already precipitated; but to prolong it more than fifteen minutes seems unreasonable, and is certainly prejudicial, inasmuch as portions of the saccharine matter will be decomposed, as before stated. The criterion which appears to regulate the time of the boiling in breweries, is the formation of a mass of insoluble or precipitated matter; but the great object should be the coagulation of the particles, and their falling to the bottom in the copper should not be so much regarded, for, during the fermentation, whilst the yet soluble portion of gluten is becoming insoluble in the form of yeast, these will be carried away mechanically in the eviscerated matter, or deposited during the cleansing, without proving injurious to the liquor.

From these considerations it follows, that the worts should not be subjected to a protracted ebullition, with the view of removing the albuminous ingredient, it being sufficient merely to render it insoluble in the menstruum; and whether it remains in the copper, is retained in the hop-back, or passes along to the fermenting tun, to be there finally and entirely removed with the barm, is a matter of no very great moment, since it is deprived of the possibility of decomposing by oxidation within this period.

These observations refer solely to the action of boiling on the wort singly, and now the effect of boiling on the hop will be considered.

It will be observed, from the notice already taken of the hop, that its efficacy as to flavor and bitterness depends upon the volatile aromatic oil which it contains, and the resin which is abstracted; it likewise communicates astringency, in consequence of the tannic acid, or tannin which it yields. The gum and other matters removed from the flowers by water are of no very great interest. Essential oils in general are dissipated by a temperature of 212°, notwithstanding that their boiling point is considerably above this standard. If hops be macerated with water and subjected to distillation, the whole, or chief portion, of the oil will very readily pass over into the receiver, leaving the solution in the retort almost entirely destitute of aroma, but retaining the bitterness and astringency in a very marked degree. This is well known to brewers generally; and those who show some regard to facts, curtail in practice the time of boiling, or make such deviations from the old-established routine, as seem to them best adapted for the retention of the aroma. It was with this view that the close boiler was introduced, and that a reservoir or tank, through which the steam from the wort was conveyed, was subsequently placed in connection with it, for the avowed purpose of catching the oil of the hop in its flight, and using the water thus impregnated in the succeeding brewings; yet the inefficiency of this arrangement might have been readily understood, by simply consulting a chemical manual, or any one conversant with such matters; for the boiling to which such worts were submitted, acted in direct opposition to the object of retaining the volatile oil.

Were the *condition* or valuable portion of the hop extracted in such a way as to retain the volatile aromatic oil, there is no doubt the beer would be greatly improved in quality. TIZARD has made an effort in this direction, by introducing his *hop-converter*, as it is termed; by the use of which, he says, the most agreeable constituents are abstracted for the better kinds of ale, and, if it be deemed necessary, the coarser portions may be used up in the inferior products. His method of doing this is by converting the lower part of the under-back into a hop-back, by inserting a perforated floor above the true bottom of the mash-tun. Upon the solid bottom of this new hop-back, or above it, but beneath the perforated plates, coils of tubing are laid, through which steam from an adjacent boiler is forced, and for facility of management there should be a steam-cock fixed in the entrance pipe to regulate the flow of vapor. The hops, after being thoroughly broken up, are laid evenly upon the perforated floor of the hop-converter, four hours before setting the tap, and as much hot water poured upon them from the heated liquor-back as will effect their saturation completely; they are then left to digest for one hour, after which the steam is passed through the convoluted pipe till the mixture has attained a temperature of 200° Fahr., retaining it at this point for the remainder of the time, till the setting of the tap. The steam is then turned off, and the wort let in upon the hops to the depth of six inches, when the pump is worked, and the goods discharged upon the coolers, taking the precaution to preserve the depth of six inches of liquor upon the hops during the time of racking and sparging. In this way, the patentee asserts, the value of the hop is retained; for the temperature during the digestion being 12° below the boiling point, very little vapor is expelled; but as it serves to withdraw the whole of the valuable constituents, and the worts are in contact with the hops during the exhaustion of the grist with the hot liquor—all the taps being open—the whole of their extract and essence is carried off in the goods.

In operating thus, it will be observed that TIZARD discards boiling the worts, but this is in some measure compensated by raising the heat of the mash towards the time of drawing off the wort to a temperature of 200° or upwards, by means of his attemperator, for the purpose of coagulating the albumen, and maintaining this degree for twenty minutes, or half an hour, as may seem best. Were the whole of the starch already converted into sugar, there is little doubt but that a method of steam boiling would be most suitable and economical; and as to the means of hopping, could the whole of the lupulin be extracted by it, the operation would be decidedly preferable to the system of boiling under high pressure for one, two, or more hours, now almost universally followed. Steam boiling also supplants the several costly requisites which enter into the brewer's stock of apparatus and material, and thus effects a saving in the plant, while the work performed will, by proper management, be as effectual, and more satisfactory, than when accomplished by the various coppers and furnaces.

Other contrivances have of late been resorted to for dispensing with boiling the worts and hops together, to obviate the danger of losing the aromatic constituents. Among these, the patent of NEWTON, of London, may be instanced; this gentleman prepares the extract from the hops, and then disposes of it to the brewer.

The same method has been followed for some time in France and some parts of the Continent, but the brewers in the United Kingdom do not appear to appreciate it. NEWTON'S mode of preparing the extract is as follows:—After having dried the hops at a low heat till they become so brittle as to be easily pulverized, the powder is passed through a coarse sieve for the purpose of retaining any stalks or pieces of wood which might be accidentally present; it is then put into a close vessel, and strong spirit of wine or alcohol poured over it till the whole becomes charged; this mixture is allowed to repose for twenty-four hours, after which the alcoholic tincture is drawn off into an appropriate receiver, and the residual powder washed as long as any extract is obtained.

The next course is to distil off the alcohol, by which means the oil and resinous body are left, mixed with a little water, which is also dispersed, first on the sand-bath, and finally on the water-bath. The aqueous washings of the powdered leaves, which contain almost the whole of the resin, are also evaporated till the water is expelled; and when this is accomplished, and while the resinous matter is still warm, the oily body procured from the alcoholic tincture is added, and intimately mixed with it. Such is the humulin of the patent processes, one pound of which is said to be as efficacious as three pounds of flowers. By adopting any of these methods, the waste of wort occasioned by the absorption of the hops would be avoided, and the products would in every respect be superior to what can be produced by boiling hops and wort together. The humulin could be added to the worts either after they are boiled—whether by steam or furnace heat, but previous to their being run on to the cooling or refrigerating backs—or before fermentation, as the case may be.

The brewer may suspect that the introduction of humulin is, like many other modern innovations, a mere deception, not designed for his advantage, but solely for the good of the parties who have an immediate interest in recommending it. He ought not, however, to be blinded to his own interest by such suspicions, especially if the benefit attributed to any suggested improvement is easily tested; but if it appears to be a plausible process, and not inconsistent with the testimony of scientific men, he should give it a fair trial, not pronouncing condemnation upon it before he has allowed himself an opportunity of forming a judgment on its merits.

Some well-informed men in the trade are of opinion, that without a continuous system of boiling the constituents of the hops cannot be entirely extracted. Were this really the case, the practice of boiling might be modified, and the present boiler—to which reference will be immediately made—converted into a digester, wherein the worts and hops might be heated to any desired point by means of high-pressure steam, and maintained at any eligible degree, for one, two, or more hours, till the extractive matter of the hop would be obtained, without permitting any of the steam or aroma of the flowers to escape. The boilers or digesters should, of course, have sufficient strength to resist any pressure to which they are exposed, and be furnished with the necessary appendages for ascertaining the pressure, and for introducing and withdrawing the materials when required.

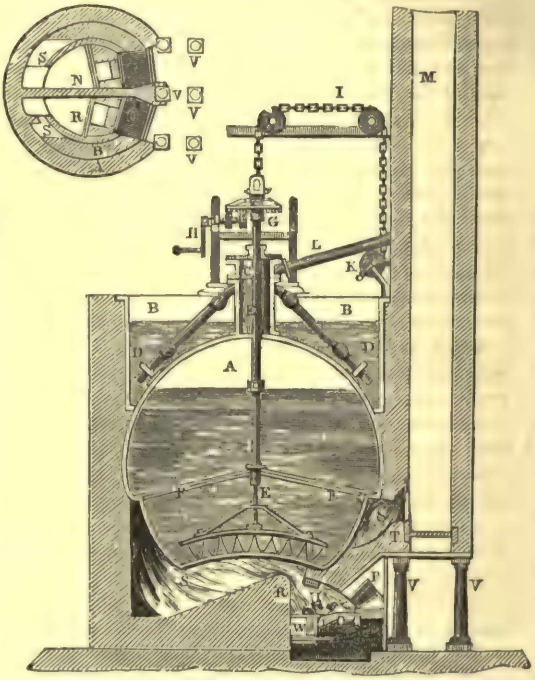
Such an arrangement is submitted as one of the many things which are deserving of trial by the enterprising brewer, and the Editor doubts not but that it would be productive of many advantages.

As yet, however, the brewers adhere to the boiling system; and as great revolutions in art and science cannot be expected to take place instantaneously, it may not be out of place to examine and discuss the system as generally carried out.

Before describing the several methods, the principal object in the boiling department will first be explained.

Figs. 161 and 162 represent the copper usually erected in breweries; the former being an elevated section, and the latter a ground plan, of the fire and flue. In fig. 161, A is the boiler or copper, hermetically sealed at the top, and convex at the bottom. Upon the top of this boiler is mounted a pan, B, in which water is heated by the caloric communicated to it during the boiling of the wort. A wide tube, C, rises from the uppermost part of the boiler, by which the steam, generated during the ebullition of the liquor, ascends, and is forced out by four tubes, two of which are seen at D D, into the liquor in the pan, B; the excess of vapor being carried off by the pipe, L, into the chimney. M. An iron shaft, E, passes down through a stuffing-box in the pipe, C, to the bottom of the vessel; at the lower end it is furnished with cross arms, from which chains are suspended, so as to sweep round the vessel. This mechanism is called *the rouser*, and its object is to prevent the matter which separates during the boiling from adhering to the metal and getting charred. It is worked by a cogged wheel on the axis of the winch, H, gearing into the wheel, G; and in order to remove the weight of the shaft off the wheel, it is partly supported at the bottom by a collar of metal borne by three stays, F F. It may be lifted by a chain, I, attached to its upper end, and, passing over the pulleys, is wound round the roller, K.

Fig. 162. Fig. 161.



This vessel, when unusually large, is heated by two fires, separated by a wall, N—Fig. 162; O O are the grates whereon the fire rests, and these are supplied, not through folding doors as formerly, but by short slanting iron hoppers—seen in Fig. 161—which are kept constantly full of coals. Above these hoppers a narrow aperture is formed for the admission of air, in such proportion as is sufficient to cause the complete combustion of the smoke. A bridge, R, at the back of each fire directs the flame upwards, so as to act upon the bottom of the copper, after which the heated vapors are conducted in semicircular flues, S S, round its sides, and finally it enters the chimney, M, on the lower part of which a sliding damper plate, T, is placed for tempering the draught. When cold air is admitted at this orifice, the combustion of the fuel is immediately checked. Besides this, there is another slide plate at the entrance of the slanting flue into the chimney, for regulating the play of the flame under and round the boiler. If the plate, T, be opened, and the other one shut, the power of the fire is suspended. There is an arch of brickwork, U, over the fire, to protect the front edge of the copper from the direct action of the flame. V V are the pillars on which the chimney is supported, and W is the opening through which the cinders and ashes are drawn away.

Sometimes, instead of the steam having free access through the pipes, D D, there is a weighted metallic valve, opening outward, and so contrived, that when the substance in the interior reaches 212°, no steam is permitted to escape, and therefore it accumulates till its pressure becomes too powerful to be restrained by the weight of the valve. It then escapes, and the few degrees of extra heat which had combined with the liquid during the formation of this pressure-steam, is carried off in that which passes away, and the heat of the remainder immediately falls to 212°, when the valve closes the orifice tightly, till there is a further quantity formed which forces it open as before. In this manner the boiling is continued during the allotted time; but, instead of permitting the escape of the steam, it is conducted into water, as in the preceding figure, as well for heating the liquor as for retaining any part of the aroma which is carried away by the vapor; this water is employed in subsequent mashings.

The criterion by which practical brewers judge of the completion of the work, is the *breaking*, or the formation of numerous flocks of coagulated matter; still, with the intent of increasing the preservative principle of the hop, the boiling is continued considerably after the above characteristic makes its appearance.

The following will give an idea of the courses pursued by various persons and on different occasions:—

1st, Ordinary ales, when the grist is exhausted in two or three mashings, are boiled thus—

First wort, ...	1 hour.
Second do., ...	2 hours.

2d, When there are three worts, the boiling is for the

First wort, ...	1 hour.
Second do., ...	1½ hour.
Third do., ...	2 hours.

In these cases, the first extract is boiled forty minutes before the hops are added, and fifteen minutes after; the gyle is then racked off, and the second worts are pumped into the copper, and treated as specified above. When the ale is to be stored, the practice is to add the hops and continue the ebullition till the coagulated matter agglutinates and falls to the bottom, after which the whole contents of the boiler are discharged to the store cask, which, when full, is tightly bunged, and then permitted to remain till the fermentation and depuration are spontaneously finished. Considerable time is required in this instance, often extending to twelve, eighteen, and even twenty-four months. Instead of putting the hops into the boiler with the wort, some persons pick or rub them between the hands, and when they are completely loosened, strew them on the bottom of the store cask, and run in the hot wort upon them after three-quarters of an hour's boil; when the cask is full it is bunged, as in the foregoing instance, and, if considered necessary, a safety-valve is appended. The fermentation and cleansing take place as in the preceding case. Where the object is to procure a highly-flavored aromatic ale, this practice is no doubt successful, especially when the hops are used in larger quantities than in ordinary cases; but in a commercial establishment the plan is now never adopted, though at one time it was much followed. Another custom is to macerate about a fourth of the hops with the worts, and boil, the remainder being reserved in the tun to be digested with the goods during the time allotted for the slow progressive fermentation, *et cetera.*

The trading brewers, in numerous cases, vary their operations, apparently with little advantage; but the following seems to be the usual routine:—Whilst the wort is being pumped into the copper, the hops are weighed out, according to the allowance per quarter, picked, and thrown on the surface of the liquor, when the boiling is performed in the open pan; but macerated with it when the closed copper is used. The layer of hops excludes contact with the air to some extent till the wort rises to ebullition, and thus any injury which might arise by spontaneous decomposition, till the temperature of the liquor reaches to 212°, is avoided. For some time the steam is allowed to permeate the hops to open their pores, for the abstraction of their bitter and other constituents, before they are beaten into the wort, and the boiling continued till the formation of the flocks, or for a specified time, say one, two, or, in case of stock ales which are exported, for three hours. In addition to the albumen which would separate from the worts by mere boiling, the tannin of the hop unites with a further quantity and precipitates it, leaving the menstruum comparatively purer, and impregnated with the preservative bitter of the flower.

The quantity of hops added to the wort is dependent upon the quality of the product and the strength of the worts, and also upon the length of time they are to be retained, or the climate they have to endure. The quality of the flowers has also an influence upon the proportion required to communicate the requisite properties to the liquor. For this reason the ales prepared for the export trade, such as East India pale ales, *et cetera*, are always more richly hopped than those used for home consumption, though of late years the preceding class has been consumed at home in considerable quantities, owing to its superiority. The allowance of hops per quarter of malt will be found in the annexed table from LEVESQUE; it extends from one-eighth of a pound to fourteen pounds per quarter. Some of the finest ales made to keep good in hot climates, have a larger quantity of hops added to them than is here mentioned, amounting sometimes to eighteen or twenty-two pounds per quarter of malt, whereas the proportion allotted to the common variety is not more than from six to eight pounds, and very rarely ten pounds. It is very common to add only four pounds of hops per quarter to the wort, especially when it is of an inferior kind; as, however, the brewer is to be guided by his own taste in the production of a bitter or a mild article, the quantities laid down in the table are the only convenient advantage which can be here afforded him:—

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 pounds per quarter.

Gravity.	⅛	¼	½	¾	1	1¼	1½	1¾	2	2¼	2½	2¾
70	0·1250	0·2500	0·5000	0·7500	1·0000	1·2500	1·5000	1·7500	2·0000	2·2500	2·5000	2·7500
71	0·1267	0·2535	0·5070	0·7607	1·0142	1·2678	1·5214	1·7750	2·0285	2·2821	2·5864	2·7892
72	0·1284	0·2570	0·5140	0·7714	1·0284	1·2856	1·5428	1·8000	2·0570	2·3142	2·6228	2·8284
73	0·1301	0·2605	0·5210	0·7821	1·0426	1·3034	1·5642	1·8250	2·0855	2·3463	2·6592	2·8676
74	0·1318	0·2640	0·5280	0·7928	1·0568	1·3212	1·5856	1·8500	2·1140	2·3784	2·6956	2·9068
75	0·1335	0·2675	0·5350	0·8035	1·0710	1·3390	1·6070	1·8750	2·1425	2·4105	2·7320	2·9460
76	0·1352	0·2710	0·5420	0·8142	1·0852	1·3568	1·6284	1·9000	2·1710	2·4426	2·7684	2·9852
77	0·1369	0·2745	0·5490	0·8249	1·0994	1·3746	1·6498	1·9250	2·1995	2·4747	2·8048	3·0244
78	0·1386	0·2780	0·5560	0·8356	1·1136	1·3924	1·6712	1·9500	2·2280	2·5068	2·8412	3·0636
79	0·1403	0·2815	0·5630	0·8463	1·1278	1·4102	1·6920	1·9750	2·2565	2·5389	2·8776	3·1028
80	0·1420	0·2850	0·5700	0·8570	1·1420	1·4280	1·7140	2·0000	2·2850	2·5710	2·9140	3·1420
81	0·1437	0·2885	0·5770	0·8677	1·1562	1·4458	1·7354	2·0250	2·3135	2·6031	2·9504	3·1812
82	0·1454	0·2920	0·5840	0·8784	1·1704	1·4636	1·7568	2·0500	2·3420	2·6352	2·9868	3·2204
83	0·1471	0·2955	0·5910	0·8891	1·1846	1·4814	1·7782	2·0750	2·3705	2·6673	3·0232	3·2596
84	0·1488	0·2990	0·5980	0·8998	1·1988	1·5092	1·7996	2·1000	2·3990	2·6994	3·0596	3·2988
85	0·1505	0·3025	0·6050	0·9105	1·2130	1·5260	1·8210	2·1250	2·4275	2·7315	3·0960	3·3380
86	0·1522	0·3060	0·6120	0·9212	1·2272	1·5438	1·8424	2·1500	2·4560	2·7636	3·1324	3·3772
87	0·1539	0·3095	0·6190	0·9319	1·2414	1·5616	1·8638	2·1750	2·4845	2·7957	3·1688	3·4164
88	0·1556	0·3130	0·6260	0·9426	1·2556	1·5794	1·8852	2·2000	2·5130	2·8278	3·2052	3·4556
89	0·1573	0·3165	0·6330	0·9533	1·2698	1·5972	1·9066	2·2250	2·5415	2·8599	3·2416	3·4948
90	0·1590	0·3200	0·6400	0·9640	1·2840	1·6050	1·9280	2·2500	2·5700	2·8920	3·2780	3·5340
91	0·1607	0·3235	0·6470	0·9747	1·2982	1·6228	1·9494	2·2750	2·5985	2·9240	3·3144	3·5732
92	0·1624	0.3270	0·6540	0·9854	1·3124	1·6406	1·9708	2·3000	2·6270	2·9562	3·3508	3·6124
93	0·1641	0·3305	0·6610	0·9961	1·3266	1·6584	1·9922	2·3250	2·6555	2·9883	3·3872	3·6156
94	0·1658	0·3340	0·6680	1·0068	1·3408	1·6762	2·0136	2·3500	2·6840	3·0204	3·4236	3·6908
95	0·1675	0·3375	0·6750	1·0175	1·3550	1·6940	2·0350	2·3750	2·7125	3·0525	3·4600	3·7300
96	0·1692	0·3410	0·6820	1·0282	1·3692	1·7118	2·0564	2·4000	2·7410	3·0846	3·4964	3·7692
97	0·1709	0·3445	0·6890	1·0389	1·3834	1·7296	2·0778	2·4250	2·7695	3·1167	3·5328	3·8084
98	0·1726	0·3480	0·6960	1·0496	1·3976	1·7474	2·0992	2·4500	2·7980	3·1488	3·5692	3·8476
99	0·1743	0·3515	0·7030	1·0603	1·4118	1·7652	2·1206	2·4750	2·8265	3·1809	3·6056	3·8868
100	0·1760	0·3550	0·7100	1·0710	1·4260	1·7830	2·1423	2·5000	2·8550	3·2130	3·6420	3·9260
101	0·1777	0·3580	0·7170	1·0817	1·4402	1·8008	2·1634	2·5250	2·8835	3·2451	3·6784	3·9652
102	0·1794	0·3620	0·7240	1·0924	1·4544	1·8186	2·1848	2·5500	2·9120	3·2772	3·7148	4·0044
103	0·1811	0·3655	0·7310	1·1031	1·4686	1·8364	2·2062	2·5750	2·9405	3·3093	3·7512	4·0436
104	0·1828	0·3698	0·7380	1·1008	1·4828	1·8542	2·2276	2·6000	2·9690	3·3414	3·7876	4·0828
105	0·1845	0·3725	0·7450	1·1245	1·4970	1·8720	2·2490	2·6250	2·9975	3·3735	3·8240	4·1220

TABLE continued.

Gravity.	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾
70	3·0000	3·2500	3·5000	3·7500	4·0000	4·2500	4·5000	4·7500	5·0000	5·2500	5·5000	5·7500
71	3·0428	3·2964	3·5500	3·8035	4·0571	4·3107	4·5642	4·8178	5·0714	5·3250	5·5785	5·8321
72	3·0856	3·3428	3·6000	3·8570	4·1142	4·3714	4·6284	4·8856	5·1428	5·4000	5·6570	5·9142
73	3·1284	3·3892	3·6500	3·9705	4·1713	4·4321	4·6926	4·9534	5·2142	5·4750	5·7355	5·9963
74	3·1712	3·4356	3·7000	3·9640	4·2284	4·4928	4·7568	5·0212	5·2856	5·5500	5·8140	6·0784
75	3·2140	3·4820	3·7500	4·0175	4·2855	4·5535	4·8210	5·0890	5·3570	5·6250	5·8925	6·1605
76	3·2568	3·5284	3·8000	4·0710	4·3426	4·6142	4·8852	5·1568	5·4284	5·7000	5·9710	6·2426
77	3·2996	3·5748	3·8500	4·1245	4·3994	4·6749	4·9494	5·2246	5·4998	5·7750	6·0495	6·3247
78	3·3424	3·6212	3·9000	4·1780	4·4568	4·7356	5·0136	5·2924	5·5712	5·8500	6·1280	6·4068
79	3·3852	3·6676	3·9500	4·2315	4·5139	4·7963	5·0778	5·3602	5·6426	5·9250	6·2065	6·4889
80	3·4280	3·7140	4·0000	4·2850	4·5710	4·8570	5·1420	5·4280	5·7140	6·0000	6·2850	6·5710
81	3·4708	3·7604	4·0500	4·3385	4·6281	4·9177	5·2062	5·4958	5·7854	6·0750	6·3635	6·6531
82	3·5136	3·8068	4·1000	4·3920	4·6852	4·9784	5·2704	5·5636	5·8568	6·1500	6·4420	6·7352
83	3·5564	3·8532	4·1500	4·4455	4·7423	5·0391	5·3346	5·6314	5·9282	6·2250	6·5205	6·8173
84	3·5992	3·8996	4·2000	4·4990	4·7994	5·0998	5·3998	5·6992	5·9996	6·3000	6·5990	6·8994
85	3·6420	3·9460	4·2500	4·5525	4·8565	5·1605	5·4630	5·7670	6·0710	6·3750	6·6775	6·9815
86	3·6848	3·9924	4·3000	4·6060	4·9136	5·2212	5·5272	5·8348	6·1424	6·4500	6·7560	7·0636
87	3·7276	4·0388	4·3500	4·6595	4·9707	5·2819	5·5914	5·9026	6·2138	6·5250	6·8345	7·1457
88	3·7704	4·0852	4·4000	4·7130	5·0278	5·3426	5·6556	5·9704	6·2852	6·6000	6·9130	7·2278
89	3·8132	4·1316	4·4500	4·7665	5·0849	5·4033	5·7198	6·0382	6·3566	6·6750	6·9915	7·3099
90	3·8560	4·1780	4·5000	4·8200	5·1420	5·4640	5·7840	6·1060	6·4280	6·7500	7·0700	7·3920
91	3·8988	4·2244	4·5500	4·8735	5·1991	5·5247	5·8482	6·1738	6·4994	6·8250	7·1485	7·4741
92	3·9416	4·2708	4·6000	4·9270	5·2562	5·5854	5·9124	6·2416	6·5708	6·9000	7·2270	7·5562
93	3·9844	4·3172	4·6500	4·9805	5·3133	5·6461	5·9766	6·3094	6·6422	6·9750	7·3055	7·6383
94	4·0272	4·3636	4·7000	5·0340	5·3704	5·7068	6·0408	6·3772	6·7136	7·0500	7·3840	7·7204
95	4·0700	4·4100	4·7500	5·0875	5·4275	5·7675	6·1050	6·4450	6·7850	7·1250	7·4625	7·8025
96	4·1128	4·4564	4·8000	5·1410	5·4846	5·8282	6·1692	6·5128	6·8564	7·2000	7·5410	7·8846
97	4·1556	4·5028	4·8500	5·1945	5·5417	5·8889	6·2334	6·5806	6·9278	7·2750	7·6195	7·9667
98	4·1984	4·5492	4·9000	5·2480	5·5988	5·9496	6·2976	6·6484	6·9992	7·3500	7·6980	8·0488
99	4·2412	4·5956	4·9500	5·3015	5·6559	6·0103	6·3618	6·7162	7·0706	7·4250	7·7765	8·1309
100	4·2840	4·6420	5·0000	5·3550	5·7130	6·0710	6·4260	6·7840	7·1420	7·5000	7·8550	8·2130
101	4·3268	4·6884	5·0500	5·4085	5·7701	6·1317	6·4902	6·8518	7·2134	7·5750	7·9335	8·2951
102	4·3696	4·7348	5·1000	5·4620	5·8272	6·1924	6·5544	6·9196	7·2848	7·6500	8·0120	8·3772
103	4·4124	4·7812	5·1500	5·5155	5·8843	6·2531	6·6186	6·9874	7·3562	7·7250	8·0905	8·4593
104	4·4552	4·8276	5·2000	5·5690	5·9414	6·3138	6·6828	7·0552	7·4276	7·8000	8·1690	8·5414
105	4·4980	4·8740	5·2500	5·6225	5·9985	6·3745	6·7470	7·1230	7·4990	7·8750	8·2475	8·6235

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 pounds per quarter.—Continued.

Gravity.	6	6¼	6½	6¾	7	7¼	7½	7¾	8	8¼	8½
70	6·0000	6·2500	6·5000	6·7500	7·0000	7·2500	7·5000	7·7500	8·0000	8·2500	8·5000
71	6·0857	6·3392	6·5928	6·8464	7·1000	7·3535	7·6071	7·8607	8·1142	8·3678	8·6214
72	6·1714	6·4284	6·6856	6·9428	7·2000	7·4570	7·7142	7·9714	8·2284	8·4856	8·7428
73	6·2571	6·5176	6·7784	7·0392	7·3000	7·5605	7·8213	8·0821	8·3426	8·6034	8·8642
74	6·3428	6·6068	6·8712	7·1356	7·4000	7·6640	7·9284	8·1928	8·4568	8·7212	8·9850
75	6·4285	6·6960	6·9640	7·2320	7·5000	7·7675	8·0355	8·3035	8·5710	8·8390	9·1070
76	6·5142	6·7852	7·0568	7·3284	7·6000	7·8710	8·1426	8·4142	8·6852	8·9568	9·2284
77	6·5999	6·8744	7·1496	7·4240	7·7000	7·9745	8·2497	8·5249	8·7994	9·0746	9·3498
78	6·6856	6·9636	7·2424	7·5212	7·8000	8·0780	8·3568	8·6356	8·9136	9·1924	9·4712
79	6·7713	7·0528	7·3352	7·6176	7·9000	8·1815	8·4639	8·7463	9·0278	9·3102	9·5927
80	6·8570	7·1420	7·4280	7·7140	8·0000	8·2850	8·5710	8·8570	9·1420	9·4280	9·7140
81	6·9427	7·2312	7·5208	7·8104	8·1000	8·3885	8·6781	8·9677	9·2562	9·5458	9·8354
82	7·0284	7·3204	7·6136	7·9068	8·2000	8·4920	8·7852	9·0784	9·3704	9·6636	9·9568
83	7·1141	7·4096	7·7064	8·0032	8·3000	8·5955	8·8923	9·1891	9·4846	9·7814	10·0782
84	7·1998	7·4988	7·7992	8·0996	8·4000	8·6996	8·9994	9·2998	9·5998	9·8992	10·1996
85	7·2855	7·5880	7·8920	8·1960	8·5000	8·8025	9·1065	9·4105	9·7130	10·0170	10·3210
86	7·3712	7·6772	7·9848	8·2924	8·6000	8·9060	9·2136	9·5212	9·8272	10·1348	10·4424
87	7·4569	7·7664	8·0776	8·3888	8·7000	9·0005	9·3207	9.6319	9·9414	10·2526	10·5638
88	7·5426	7·8556	8·1704	8·4852	8·8000	9·1130	9·4278	9·7426	10·0516	10·3704	10·6852
89	7·6283	7·9448	8·2632	8·5816	8·9000	9·2165	9·5349	9·8533	10·1698	10·4882	10·8006
90	7·7140	8·0340	8·3560	8·6780	9·0000	9·3200	9·6420	9·9640	10·2840	10·6060	10·9280
91	7·7997	8·1232	8·4488	8·7744	9·1000	9·4235	9·7491	10·0747	10·3982	10·7238	11·0494
92	7·8854	8·2124	8·5416	8·8708	9·2000	9·5270	9·8562	10·1854	10·5124	10·8416	11·1708
93	7·9771	8·3016	8·6344	8·9672	9·3000	9·6305	9·9633	10·2961	10·6266	10·9514	11·2922
94	8·0568	8·3908	8·7272	9·0636	9·4000	9·7340	10·0704	10·4068	10·7408	11·0772	11·4136
95	8·1425	8·4800	8·8200	9·1600	9·5000	9·8375	10·1775	10·5175	10·8550	11·2950	11·5350
96	8·2282	8·5692	8·9128	9·2564	9·6000	9·9410	10·2846	10·6282	10·9692	11·3128	11·6564
97	8·3139	8·6584	9·0056	9·3528	9·7000	10·0445	10·3917	10·7389	11·0834	11·4306	11·7778
98	8·3996	8·7476	9·0984	9·4492	9·8000	10·1480	10·4988	10·8496	11·1976	11·5484	11·8992
99	8·4853	8·8368	9·1912	9·5456	9·9000	10·2515	10·6059	10·9603	11·3118	11·6662	12·0206
100	8·5710	8·9260	9·2840	9·6420	10·0000	10·3550	10·7130	11·0710	11·4260	11·7840	12·1420
101	8·6567	9·0152	9·3768	9·7384	10·1000	10·4585	10·8201	11·1817	11·5402	11·9018	12·2634
102	8·7424	9·1044	9·4696	9·8348	10·2000	10·5620	10·9272	11·2924	11·6544	12·0196	12·3848
103	8·8281	9·1936	9·5624	9·9312	10·3000	10·6655	11·0343	11·4031	11·7686	12·1374	12·5062
104	8·9138	9·2828	9·6552	10·0276	10·4000	10·7690	11·1414	11·5138	11·8828	12·2552	12·6267
105	8·9995	9·3720	9·7480	10·1240	10·5000	10·8725	11·2485	11·6245	11·9970	12·3730	12·7490

TABLE continued.

Gravity.	8¾	9	9¼	9½	9¾	10	10¼	10½	10¾	11	11¼
70	8·7500	9·0000	9·2500	9·5000	9·7500	10·0000	10·2500	10·5000	10·7500	11·0000	11·2500
71	8·8750	9·1285	9·3821	9·6357	9·8892	10·1428	10·3964	10·6500	10·9035	11·1571	11·4107
72	9·0000	9·2570	9·5142	9·7714	10·0284	10·2856	10·5428	10·8000	11·0570	11·3142	11·5714
73	9·1250	9·3855	9·6463	9·9071	10·1676	10·4284	10·6892	10·9500	11·2105	11·4713	11·7321
74	9·2500	9·1140	9·7784	10·0428	10·3068	10·5712	10·8356	11·1000	11·3640	11·6284	11·8928
75	9·3750	9·6465	9·9105	10·1785	10·4460	10·7140	10·9820	11·2500	11·5175	11·7855	12·0535
76	9·5000	9·7710	10·0426	10·3142	10·5852	10·8568	11·1284	11·4000	11·6710	11·9426	12·2142
77	9·6250	9·8995	10·1747	10·4499	10·7244	10·9996	11·2748	11·5500	11·8245	12·0997	12·3749
78	9·7500	10·0280	10·2068	10·5856	10·8636	11·1424	11·4212	11·7000	11·9780	12·2568	12·5356
79	9·8750	10·1565	10·4389	10·7213	11·0028	11·2852	11·5676	11·8500	12·1315	12·4139	12·6963
80	10·0000	10·2850	10·5710	10·8570	11·1420	11·4280	11·7140	12·0000	12·2850	12·5710	12·8570
81	10·1250	10·4135	10·7031	10·9927	11·2812	11·5708	11·8604	12·1500	12·4385	12·7281	13·0177
82	10·2500	10·5420	10·8352	11·1284	11·4204	11·7136	12·0068	12·3000	12·5920	12·8852	13·1784
83	10·3750	10·6705	10·9673	11·2641	11·5296	11·8564	12·1532	12·4500	12·7455	13·0423	13·3391
84	10·5000	10·7990	11·0994	11·3998	11·6988	11·9992	12·2996	12·6000	12·8990	13·1994	13·4998
85	10·6250	10·9275	11·2315	11·5355	11·8380	12·1420	12·4460	12·7500	13·0525	13·3565	13·6605
86	10·7500	11·0560	11·3636	11·6712	11·9772	12·2848	12·5924	12·9000	13·2660	13·5136	13·8212
87	10·8750	11·1845	11·4957	11·8069	12·1164	12·4276	12·7388	13·0500	13·3595	13·6707	13·9819
88	11·0000	11·3130	11·6278	11·9426	12·2556	12·5704	12·8852	13·2000	13·5130	13·8278	14·1426
89	11·1250	11·4415	11·7599	12·0783	12·3948	12·7132	13·0316	13·3500	13·6665	13·9849	14·3033
90	11·2500	11·5700	11·8920	12·2140	12·5340	12·8560	13·1780	13·5000	13·8200	14·1420	14·4640
91	11·3750	11·6985	12·0241	12·3497	12·6732	12·9988	13·3244	13·6500	13·9735	14·2991	14·6247
92	11·5000	11·8270	12·1562	12·4854	12·8124	13·1416	13·4708	13·8000	14·1270	14·4562	14·7854
93	11·6250	11·9555	12·2883	12·6211	12·9516	13·2844	13·6172	13·9500	14·2805	14·6133	14·9461
94	11·7500	12·0840	12·4204	12·7568	13·0908	13·4272	13·7636	14·1000	14·4340	14·7704	15·1068
95	11·8750	12·2125	12·5525	12·8925	13·2300	13·5700	13·9100	14·2500	14·5875	14·9275	15·2675
96	12·0000	12·4410	12·6846	13·0282	13·3692	13·7128	14·0564	14·4000	14·7410	15·0846	15·4282
97	12·1250	12·5695	12·8167	13·1639	13·5084	13·8556	14·2028	14·5500	14·8945	15·2417	15·5899
98	12·2500	12·6980	12·9488	13·2996	13·6476	13·9984	14·3492	14·7000	15·0480	15·3988	15·7496
99	12·3750	12·8265	13·0809	13·4353	13·7868	14·1412	14·4496	14·8500	15·2015	15·5559	15·9103
100	12·5000	12·9550	13·2130	13·5710	13·9260	14·2840	14·6420	15·0000	15·3550	15·7130	16·0710
101	12·6250	13·0835	13·3451	13·7067	14·0652	14·4268	14·7884	15·1500	15·5085	15·8701	16·2317
102	12·7500	13·2120	13·4772	13·8424	14·2044	14·5696	14·9348	15·3000	15·6620	16·0272	16·3924
103	12·8750	13·3405	13·5093	13·9781	14·3436	14·7124	15·0812	15·4500	15·8155	16·1843	16·5531
104	13·0000	13·4680	13·7414	14·1138	14·4828	14·8552	15·2276	15·6000	15·9690	16·3414	16·7138
105	13·1250	13·5965	13·8735	14·2495	14·6220	14·9980	15·3740	15·7500	16·1225	16·4985	16·8745

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 lbs. per quarter.—Concluded.

Gravity.	11½	11¾	12	12¼	12½	12¾	13	13¼	13½	13¾	14
70	11·5000	11·7500	12·0000	12·2500	12·5000	12·7500	13·0000	13·2500	13·5000	13·7500	14·0000
71	11·6612	11·9178	12·1714	12·4250	12·6785	12·9321	13·1857	13·4392	13·6928	13·9464	14·2000
72	11·8284	12·0856	12·3428	12·6000	12·8570	13·1142	13·3714	13·6284	13·8865	14·1428	14·4000
73	11·9926	12·2534	12·5412	12·7750	13·0320	13·2963	13·5571	13·8176	14·0784	14·3392	14·6000
74	12·1568	12·4212	12·6856	12·9500	13·2105	12·4784	13.7428	14·0068	14·2712	14·5356	14·8000
75	12·3210	12·5890	12·8570	13·1250	13·3890	13·6605	13·9285	14·1960	14·4640	14·7320	15·0000
76	12·4852	12·7568	13·0284	13·3000	13·5675	13·8426	14·1142	14·3852	14·6568	14·9284	15·2000
77	12·6494	12·9246	13·1998	13·4750	13·7460	14·0247	14·2999	14·5744	14·8496	15·1248	15·4000
78	12·8136	13·0924	13·3712	13·6500	13·9245	14·2068	14·4856	14·7636	15·0424	15·3212	15·6000
79	12·9778	13·2602	13·5426	13·8250	14·1030	14·3889	14·6713	14·9528	15·2352	15·5176	15·8000
80	13·1420	13·4280	13·7140	14·0000	14·2815	14·5710	14·8570	15 1410	15·4280	15·7140	16·0000
81	13·3062	13·5958	13·8885	14·1750	14·4600	14·7531	15·0427	15·3302	15·6208	15·9404	16·2000
82	13·4704	13·7636	14·0568	14·3500	14·6385	14·9352	15·2284	15·5194	15·8136	16·1068	16·4000
83	13·6346	13·9314	14·2282	14·5250	14·8170	15·1173	15·4141	15·7086	16·0064	16·3032	16·6000
84	13·7988	14·0992	14·3996	14·7000	14·9955	15·2994	15·5998	15·8978	16·1992	16·4996	16·8000
85	13·9630	14·2670	14·5710	14·8750	15·1740	15·4815	15·7855	16·0870	16·3920	16·6960	17·0000
86	14·1272	14·4348	14.7424	15·0500	15·3525	15·6636	15·9712	16·2762	16·5848	16·8924	17·2000
87	14·2914	14·6026	14·9138	15·2250	15·5310	15·8457	16·1569	16·4654	16·7776	17·0888	17·4000
88	14·4556	14·7740	15·0852	15·4000	15·7095	16·0278	16·3426	16·6546	16·9704	17·2852	17·6000
89	14·6198	14·9382	15·2566	15·5750	15·8880	16·2099	16·5283	16·8438	17·1632	17·4816	17·8000
90	14 7840	15·1060	15·4280	15·7500	16·0665	16·3920	16·7146	17·0320	17·3560	17·6780	18·0000
91	14·9482	15·2738	15·5994	15·9250	16·2450	16·5741	16·8997	17·2212	17·5488	17·8744	18·2000
92	15·1124	15·4416	15·7708	16·1000	16·4235	16·7562	17·0854	17·4104	17·7416	18·0708	18·4000
93	15·2766	15·6694	15·9422	16·2750	16·6020	16·9383	17·2711	17·6096	17·9344	18·2672	18·6000
94	15·4408	15·7772	16·1136	16·4500	16·7805	17·1204	17·4568	17·7988	18·1272	18·4636	18·8000
95	15·6050	15·9450	16·2850	16·6250	16·9590	17·3025	17·6425	17·9880	18·3200	18·6600	19·0000
96	15·7692	16·1128	16·4564	16·8000	17·1375	17·4846	17·8282	18·1772	18·5128	18·8564	19·2000
97	15·9334	16·2806	16·6278	16·9750	17·3160	17·6667	18·0139	18·3664	18·7056	19·0528	19·4000
98	16·0976	16·4484	16·7992	17·1500	17·4945	17·8488	18·1996	18·5556	18·8984	19·2492	19·6000
99	16·2618	16·6162	16·9706	17·3250	17·6730	18·0309	18·3853	18·7448	19·0912	19·4456	19·8000
100	16·4260	16·7840	17·1420	17·5000	17·8515	18·2130	18·5710	18·9340	19·2840	19·6420	20·0000
101	16·5902	16·9518	17·3134	17·6750	18·0300	18·3951	18·7567	19·1232	19·4768	19·8384	20·2000
102	16·7544	17·1196	17·4848	17·8500	18·2085	18·5772	18·9424	19·3124	19·6696	20·0348	20·4000
103	16·9186	17·2874	17·6562	18·0250	18·3870	18·7593	19·1281	19·5016	19·8624	20·2312	20·6000
104	17·0828	17·4552	17·8276	18·2500	18·5655	18·9414	19·3138	19·6908	20 0552	20·4276	20·8000
105	17·2470	17·6230	17·9990	18·3750	18·7440	19·1235	19·4995	19·8800	20·2480	20·6240	21·0000

If the produce of the malt be obtained in two or more mashings, and they are boiled separately, the proportion of hops which each wort will require is found as follows:—Suppose the quantity taken was eighty quarters of malt, and that the gravity per quarter is eighty-five pounds, the whole being extracted in two mashes, the first of which tests sixty-five pounds, and the other, together with the washings, twenty pounds per quarter; further, if the proportion of hops to the quarter of seventy pounds gravity be twelve pounds, by referring to the gravity, eighty-five pounds in the table, the number 14·571 will be found on the horizontal line under the head of twelve pounds per quarter. Then 85 × 14·571 = 1238·5 pounds of hops, and 80 × 85 = 6800 pounds, the total extract; and 6800 ÷ 1238·5 = 0·1821 pounds of hops for each pound gravity in each of the worts; and hence 65 × 80 × 0·182 = 946·9 pounds for the first wort, 20 × 80 × 0·182 = 291·6 pounds for the second wort.

In a similar way, the proportion of the flowers which ought to be added to the several liquors is found, at whatever number of pounds per quarter, as specified in the table, is adopted.

Sometimes the whole of the hops is added to the first wort; but the time of boiling is shortened, so as to leave sufficient of the bitter principle for the next liquor; the practice most frequently followed is to add the proper quantity to each wort and discharge the whole, when the usual time of boiling is expired, into the hop-back. The ebullition in this case is continued for one half to three quarters of an hour longer in the second than in the first wort, to remove the excess of impurities which the after mashings generally carry along with them, and to exhaust the hops, as well as to concentrate the gyle, and procure a better quality of ale than they would afford in their diluted state. The brewer, however, applies here only an imperfect remedy for the self-inflicted malady of drawing off repeated mashings in a very diluted state, for by such a course of ebullition the sugar is partly decomposed as already explained, the menstruum deepens in color, and the expenditure in fuel becomes a dead loss; whereas, if the precautions alluded to in the foregoing pages be observed, most of these disadvantages will not be experienced. After the boiling, the gyle and hops are drawn off to the hop-back, and the liquor is made to percolate through the hops used in the foregoing operation. Any strong wort which might be retained in the exhausted hops is carried off in the second gyle, and what is retained of the second is washed off with hot water, and the washings preserved for a return wort; or in case light ales are to be made, added to the product in the cooler; or the residuary fibrous matter of the hops is removed to the press, and the liquor squeezed out in this way added to the second gyle.

A larger quantity of hops is always used in hot weather than when the air is cold or mild, so as to prevent the decomposition of the ale, which, without this counteracting agent, the elevated temperature would occasion.

The following table, transcribed from LEVESQUE, specifies the increase of hops required for every degree from 50° to 75° Fahr., and from four to nine pounds per quarter:—

Temperature of the air at the time of brewing	Four pounds per quarter.	Five pounds per quarter.	Six pounds per quarter.	Seven pounds per quarter.	Eight pounds per quarter.	Nine pounds per quarter
50°	4·00	5·00	6·00	7·00	8·00	9·00
51	4·08	5·10	6·12	7·14	8·16	9·18
52	4·16	5·20	6·24	7·28	8·32	9·36
53	4·24	5·30	6·36	7·42	8·48	9·54
54	4·32	5·40	6·48	7·56	8·64	9·72
55	4·40	5·50	6·60	7·70	8·80	9·90
56	4·48	5·60	6·72	7·84	8·96	10·08
57	4·56	5·70	6·84	7·98	9·12	10·26
58	4·64	5·80	6·96	8·12	9·28	10·44
59	4·72	5·90	7·08	8·26	9·44	10·52
60	4·80	6·00	7·20	8·40	9·60	10·70
61	4·88	6·10	7·32	8·54	9·76	10·88
62	4·96	6·20	7·44	8·68	9·92	11·06
63	5·04	6·20	7·56	8·82	10·08	11·24
64	5·12	6·40	7·68	8·96	10·24	11·42
65	5·20	6·50	7·80	9·10	10·40	11·60
66	5·28	6·60	7·92	9·24	10·56	11·88
67	5·36	6·70	8·04	9·38	10·72	12·06
68	5·44	6·80	8·16	9·52	10·88	12·24
69	5·52	6·90	8·28	9·66	11·04	12·42
70	5·60	7·00	8·40	9·80	11·20	12·60
71	5·68	7·10	8·52	9·94	11·36	12·78
72	5·76	7·20	8·64	10·08	11·52	12·96
73	5·84	7·30	8·76	10·22	11·68	13·14
74	5·92	7·40	8·88	10·36	11·84	13·32
75	6·00	7·50	9·00	10·50	12·00	13·50

Notwithstanding that this table has evidently been drawn up from theory and not experiment, yet to practical men it may serve to some extent as a guide to direct them in weather unfavorable for brewing. The best guarantee would be to avoid as much as possible extracting the nitrogenous portions of the malt, or, when extracted, to separate them completely in the fermentation.

During the boiling, considerable quantities of water are expelled in the form of vapor, and a great difference is consequently observed between the density of the wort after boiling, and the gravity which it indicated at the time of its introduction into the copper.

The annexed table, copied also from LEVESQUE, shows what gravity the original wort ought to possess to afford a gyle of a certain strength after one hour's boiling:—

Gravity required after one hour's boiling.	Gravity required in the raw wort.	Gravity required after one hour's boiling.	Gravity required in the raw wort
8	6·60	27	21·60
9	7·20	28	22·40
10	8·00	29	23·20
11	8·80	30	24·00
12	9·60	31	24·80
13	10·40	32	25·60
14	11·20	33	26·40
15	12·00	34	27·20
16	12·80	35	28·00
17	13·60	36	28·80
18	14·40	37	29·60
19	15·20	38	30·40
20	16·00	39	31·20
21	16·80	40	32·00
22	17·60	41	32·80
23	18·40	42	33·60
24	19·20	43	34·40
25	20·00	44	35·20
26	20·80	45	36·00

According to RICHARDSON, the volume of wort imbibed by the hops is as follows:—

Hops used	Wort imbibed	Hops used.	Wort imbibed.
Pounds.	Bar.	Pounds.	Bar.
1	0·01	30	0·50
2	0·03	40	0·66
3	0·05	50	0·83
4	0·06	60	1·00
5	0·08	70	1·16
6	0·10	80	1·33
7	0·11	90	1·50
8	0·13	100	1·66
9	0·15	200	3·33
10	0·16	300	5·00
11	0·17	400	6·66
12	0·19	500	8·33
13	0·21	600	10·00
14	0·22	700	11·66
15	0·24	800	13·32
16	0·26	900	15·00
17	0·27	1000	16·66
18	0·29	2000	33·30
19	0·31	3000	50·00
20	0·33	4000	66·66

The back into which the hops and wort are discharged is usually a large square vessel of wood or iron, with a perforated false bottom and a tap appended, not unlike the construction of the mash tun. When the contents of the copper are to be drawn off, the *rouser*, or other agitating apparatus, is set in motion to raise the hops in the liquor; and when the whole is removed to the back, some time is allowed to elapse before the gyle is drawn off to the refrigerators, in order that the hops may subside, and retain any mechanical impurities which may be floating in the liquid as it filters through them. Many persons, especially in Scotland, instead of employing an apparatus like that mentioned, erect a large square, with a temporary bottom or strainer, made of hair, and into this the hops and gyle are discharged. In this case the liquor is not so transparent as in the former; but it seems to be a disputed point, whether the finer portions of the hop grains that are carried through with the coagulated albumen are serviceable as a preservative to the beer, which is maintained by the practisers of the Scotch method chiefly on the ground, that a larger quantity of albuminous and glutinous matter is deposited with the hop grains in the coolers, and that the gyle is therefore much better purified than by the practice of filtering through the hops, as in the first method.

COOLING.—After the worts are thoroughly hopped and boiled, the next thing to be done is to bring them to a proper temperature for the commencement of the fermentation, which, to insure success, must be conducted within certain limits. The liquor, in this case, must be rapidly cooled, for, if permitted to remain in contact with the air during the time its caloric would be given off spontaneously, the consequence would be, that, unless the atmosphere were very cold, acidity would set in. Two methods are resorted to for cooling the worts, both of which are to a great extent artificial. The first has been practised for a considerable period, and is, therefore, sanctioned by the great majority of brewers; but the latter, which is of recent introduction, is much more effectual, and is generally to be found in the factories of the better-informed class in the trade.

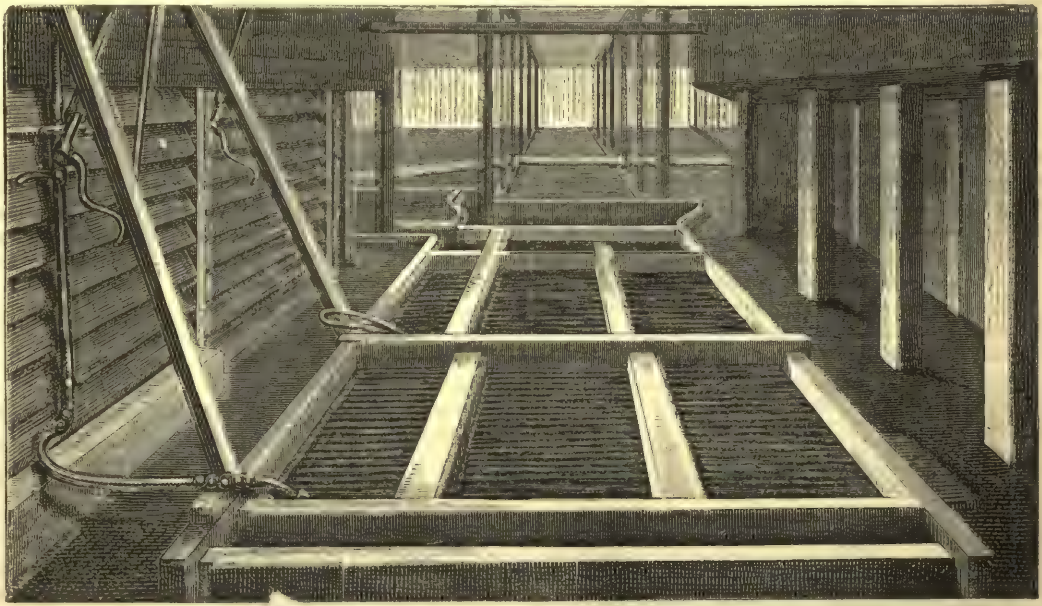
The apparatus used in the first instance is known as the *cooler*, and in the second as the *refrigerator*.

Coolers are spacious rectangular shallow vessels, for the most part constructed of Dantzic deal boards, two inches thick at the sides, and one inch and a quarter or one and a half at the bottom; these boards are connected by plain joints, to which they are secured by pins of the same wood. The depth of the cooler is about six inches, and it should be perfectly smooth, so that no impurities can be retained, which would be the case when the worts are drawn off, were any inequalities or rough knots in the floor; it should have a gentle incline towards that end at which the gyle is discharged into the fermenting-backs, and be placed in a position where the air has free access to it. For this reason the cooling floor is always in an elevated part of the brewery, and exposed on all sides by means of boards arranged in the same manner as a Venetian sun-blind. To expedite the work, fans or other mechanical agencies, similar to those noticed at page 64, are used, to increase the current of air in the apartment, whereby the heat is more readily dissipated than if allowed to radiate spontaneously. The gyle is streamed upon this floor to the depth of two or two and a half inches, and when the atmosphere is rather cold, as from the latter end of autumn to the middle of spring, the stratum cools in six to eight hours; but even this is too long for the liquor to remain exposed to the air.

Considerable loss, indeed, is often incurred by the imperfection of this method of cooling by the wooden floor, especially in warm weather, when the atmosphere is of a comparatively high temperature; for, in the first place, the liquor is not reduced in its heat so readily as to be entirely exempt from acidity; and, in the second, the wood of the vessel experiences considerable change in the alternate application of heat and cold, by which its pores are distended so much, that if allowed to remain exposed for any length of time, air enters, and this coming in contact with the gyle in the next operation, it operates on its saccharine and albuminous constituents, and occasions a creaming of the surface, or an incipient fermentation, technically known as the *fox*.

This evil may be partially prevented by keeping the floor covered with cold water, after the worts have been drawn off and the deposited matter cleaned away, till the next operation; but still the wood is liable to communicate acidity, unless the greatest attention be given to its being thoroughly washed very frequently with lime water. It is much more advisable to have the coolers constructed of some other material than wood, and, indeed, they are so formed by several brewers. Iron, when carefully attended to in point of cleansing, *et cetera*, answers very well, but tinned copper would be much more satisfactory. Sheet-iron, glazed or enamelled, would answer the purposes of the brewer admirably in this respect. **TIZARD** recommends to have the coolers formed of tiles made from felspar by a Manchester patentee, as being very eligible; and it cannot be doubted that, in point of cleanliness and security from foxing or acquiring a bad taste, such tiles would be preferable the hops and might generally answer; but still they are not so good conductors of heat as iron or copper, and hence they would not cool the liquid so readily as these metals.

Fig. 163.



The refrigerators occupy no more than one-half or three-eighths of the space which the plain coolers take up; they are constructed, like the latter, in the form of a plane, with transverse divisions or bars issuing from each side alternately, and reaching to within half a foot of the opposite side; the space between each bar is usually about a foot or a foot and a half, and in this a pipe of suitable calibre is laid, through which cold water is made to flow in an opposite direction to the current of the gyle.

Fig. 163 represents the refrigerator in use at the factory of Messrs. **Allsopp** and **Sons**; the water pipe, entering at the lower end, is seen at A, and passes off at the further end, where the hot worts are being discharged into the cooler.

When the worts are cooled on the open floor, considerable quantities of deposit are formed, which in some instances are swept off into the fermenting-backs. The chief aim of the manager should be to cool the liquor as readily as possible, especially when the temperature reaches 130° Fahr.; the floor and pipes should also be kept scrupulously clean, otherwise the goods will either acquire a very bad taste or turn acid. When refrigerators are not erected, the best way would be to have the cooling floors so constructed that they could be exposed when required. If this were done, and the worts were streamed upon them during the night in summer, they would cool very rapidly in consequence of the heat being radiated into the clear atmosphere. After the gyle is cooled to the limits of 56° to 64°, it is transferred to the fermenting squares to undergo the next process, namely,

Fermentation.—In the whole course of brewing, there is no part of the work which requires such indefatigable diligence as the fermentation of the wort, as upon it depends the perfect accomplishment of the business; for if the foregoing stages had been performed somewhat imperfectly, provided the products have not acidified, and they have been subjected to a good fermentation, a wholesome beverage is obtained; but let the mashing and the other operations be ever so studiously executed, if the fermentation is imperfect, a bad and almost worthless product results. Yet, by care and moderate experience, it may be easily managed, so as to guard against the possibility of a failure.

The principles of the vinous fermentation have been alluded to at sufficient length at page 64 *et seq.*, to which the reader is referred; and knowing, from the explanation there given, what are its effects, and wherein it has to be counteracted, the chief aim should be the acquisition of the best practical knowledge for conducting it.

It is worth observing, however, that there are various species of chemical decompositions characterized by the term fermentation, such as the *lactic*, the *mucic*, the *ammoniacal*, the *acetous*, the *panary*, the *putrid*, the *vinous*, and various others, whereby certain compounds are generated, but *always* by a direct or an indirect species of oxidation. According to the nature of the substances operated upon, one or more of these may be excited by the contact of a body undergoing the like decomposition. For instance, a compound in the state of the acetous or lactic fermentation, on being brought in contact with a solution of sugar, occasions the direct formation of either acetic or lactic acid in the liquid.

This being the case, it is evident that the greatest and most scrupulous care should be observed in selecting the barm, or store, which is employed to induce the action in the first instance, lest it may have contracted any acidity or putrefaction, which would certainly prove detrimental to the beer, as affecting its flavor, wholesomeness, and keeping properties.

The apparatus required for the fermentation are either circular tuns or squares, constructed of sheet-iron or Dantzic deal, and of a capacity suited to the quantity of materials employed; they are generally furnished with an attemperator, or pipe, through which either hot or cold water, as the temperature of the contents may be too high or too low, is transmitted. The liquid is introduced into these fermenting vessels at a temperature varying from 54° to 64° Fahr., according to the practice of different brewers. In England, the pitching heat is usually between 60° and 64°, or even higher; while in Scotland the temperature does not reach higher than 58°, except in some few cases. When the pitching heat is high, and the yeast is of a good quality and in sufficient abundance, the fermentation becomes ungovernable, unless there be an attemperator to check the rising heat; besides, the whole of the glutinous constituents of the gyle is not removed in the yeast, and the liquor does not cleanse satisfactorily, in consequence of an after fermentation which sets in, and is practically known as the *fret*. On the other hand, if the action proceeds sluggishly, so that the yeast remains in contact with the liquor at a temperature of 66° to 70° for some time, then, in addition to its being ropy, the disagreeable taste of the yeast that has to some extent entered upon the putrefactive fermentation, will be retained, and the product is what is termed *yeast-bitten.*

To guard against both these serious evils, it is necessary to be scrupulously careful that the store yeast is in a good and healthy condition, and also that the temperature is properly regulated, as well in reference to the bulk and gravity of the gyle, as to the state of the atmosphere. The practice observed by some brewers of beating the head of the yeast into the gyle, however it may seem to favor the operation, is not so indispensable as they would suppose; for if the action be engrafted in the liquid at the first, it will proceed with sufficient power to complete the work without the assistance offered by the new yeast being beaten into it.

With these considerations, the brewer may discharge his worts into the fermenting vessels at from 58° to 64°, according to the circumstances already alluded to; but, before he proceeds, it should be his duty to ascertain the mean temperature of the air in the room, to have the real density of his gyle, and the quantity in barrels and firkins noted in his book, so that he may be better able to judge of the rise of temperature, the degree of attenuation, and the waste suffered during the action, but, above all, the proportion of yeast or *store* to be added at the commencement. Various circumstances tend to influence the quantity of yeast which ought to be added to the gyle; hence, to give a definite rule in this particular is out of the question. By studious attention and moderate experience the brewer will be able to master the difficulty, especially when it is borne in mind that the variation takes place, firstly, and principally, with the quality of the store; secondly, with the degree of heat at which the malt had been dried, and the quality of the liquor used in mashing; thirdly, with the gravity of the worts; and fourthly, with the temperature of the liquor, and likewise that of the air at the time of pitching the tun.

Yeast is very variable in its effects, according to the time of its production, its succeeding management, its age and condition; for the purposes of fermentation it cannot be too fresh, to operate with energy. The best variety at present in use is collected from pale gyles, near the close of the alcoholic fermentation, and after the first or second skimming. The first portions of yeast thrown off are not solid enough, and they generally carry with them some of the liquid as well as glutinous matter not wholly transformed into yeast, which continues to undergo oxidation till the acetous or putrefactive change sets in; and it is needless to add that such yeast would be highly injurious, and ought to be avoided.

When collected as above described, it is sufficiently dense without any glutinous matter which has not undergone oxidation by the decomposition of the sugar and water of the gyle; and it is, besides, entirely protected during the period of its formation from contact with the air, and wholly free from the old store or ferment added to the liquor in the beginning. By using the yeast thus carefully provided, a much less quantity of it will be effectual than of the other kinds which may be taken at random.

If highly dried or patent malt has been taken, the yeast must be added in larger proportion than if the worts were extracted from pale malt, for the constituents of the grain undergo decomposition, in consequence of which the proportion of gluten is considerably reduced in the extract; and to make up this deficiency of matter by which new ferment is formed, and the action of the original ferment invigorated, a larger proportion of yeast must be supplied in the first instance. The same precaution must be observed when the temperature of the gyle is low, and a large amount of extract is present; for it is well known that only a definite quantity of sugar is converted into alcohol by the yeast which is added; and as soon as this transformation is effected, the ferment loses its vitality, and is incapable of furthering the action beyond this limit, so that, if there be not as much matter as will generate a natural ferment in the gyle, the excess of saccharum over the quantity which the yeast added will act upon remains intact. The temperature of the liquor and air at the period of fermenting, will greatly influence the rapidity of the fermentation; for when the degree of heat is elevated, the matter of the gyle will more readily commingle.

When the gravity of the gyle is about 45 pounds per barrel, and the temperature of setting 58° or 60° Fahr., the atmosphere being at the ordinary temperature and barometric pressure, provided the yeast be of that quality already spoken of, about two to two and a half pounds per barrel will be sufficient, and it may happen that this quantity will in some cases overstore the tun. In winter, on the contrary, the store per barrel is increased to three, and sometimes three and a half pounds; but then the heat of pitching is lower than in the preceding case.

When worts of 20, 25, 30, or 40 pounds per barrel —the usual strength of the ordinary ales—are fermented, a less weight of store must be added in proportion as their density decreases.

The intervals of adding the yeast, like the various other operations in brewing, are different with most brewers, some preferring to add the total quantity at once, while others reserve a portion to be subsequently introduced, in order to strengthen the fermentation. As in either case the results are satisfactory, the brewer must be left to his own discretion in this matter, being mindful, however, of the facts which may be gleaned from the preceding pages on the subject, and that it is necessary to have a healthy action inoculated in the gyle from the beginning, otherwise the fermentation will not be successful.

After the mixture of the yeast and gyle has been made some time, the action is observed by the rise of some minute bubbles of gas to the surface, which form on the sides of the vessels; as the operation advances, this ring of minute vesicles, or froth, as it is termed, becomes detached, and moves towards the centre, its place being in a short time occupied by another ring, which imitates its predecessor, and thus the rings succeed one another till the whole surface is covered.

The decomposition of the sugar being more perfectly engrafted in the menstruum, the liberation of carbonic acid is freer and more voluminous, and a hissing sound or effervescence is observed. The sugar being more and more rapidly decomposed, the froth swells to a larger extent, by retaining the carbonic acid in the viscid matter which rises to the top; but when the volume accumulated is so great that the tension of the yet imperfect yeast cannot restrain it, it bursts and causes inequalities in the head, which gives it the appearance of what the brewer terms *rocks*.

The froth, which hitherto was colorless, begins to be tinged yellow, and as the work proceeds, it turns either to a lightish or brownish yellow; but it is a better sign of the fermentation, if it remains of the former shade. At this period the head falls considerably, in consequence of the carbonic acid gas which accumulated during the preceding part of the operation, overcoming the elasticity of the yeast and escaping; the newly-formed yeast becomes more dense and viscid, and the fermentation is much diminished. Were the head permitted to remain in contact with the liquor after this period, it would very soon precipitate, and probably, by having entered upon a putrefactive decomposition, would give rise to the same in the liquor; at any rate, the disagreeable bitterness which characterizes stale or putrefying ferment would be discernible in the beer, and in this state, as already remarked, it is said to be yeast-bitten. To prevent such effect, the ferment is skimmed off, and by this means the cause is removed; the fermentation is also checked so as to prevent it from passing the desired limits; many, however, take off only the top surface, beat the remainder into the liquor, and continue the fermentation with renewed vigor, till all the albuminous matters are separated in the form of yeast, and the greatest part of the saccharum has been reduced to alcohol and carbonic acid. Such is the treatment usually applied to exported ales, or bitter beers, that are reserved for store.

In brewing mild ales it is necessary to have a certain quantity of the sugar unattenuated, so as to give more or less sweetness to the beverage, and therefore the barm is skimmed off, as above stated, to check the fermentation, and attain the end proposed.

It has been shown on several occasions, that when the vinous fermentation takes place in a liquor, it is always succeeded, provided the liquor be left to itself, by the acetous; it is the same in this instance, for if the fermented liquor were allowed to repose after the first action has ceased, and the product clarifies, it would in a very short time become turbid, absorb oxygen, eviscerate a mucilaginous matter—*mother of vinegar*—and turn sour. Such destruction is prevented by the cleansing process; but, before describing this operation, it will be necessary to allude to the patented and other improvements which have been lately introduced into the brewing business. In doing this, the practice so long and efficiently followed in Bavaria deserves to arrest the attention.

The great and distinguishing feature of the beers of that kingdom, which are slowly fermented, is that they do not contract any acescency when exposed to the air, whilst the products of English, Scotch, and French brewings will invariably become sour under such circumstances. In addition to this very characteristic mark of the soundness of Bavarian beers, they possess the other qualities by which good beer is always known, and hence the high estimation in which they are held by all parties. These valuable qualities are obtained by the perfect system of fermentation to which the worts are subjected, a system which in itself has solved one of the most beautiful theories connected with it. Allusion has been already made to the causes of acidity in the gyle when speaking of boiling, but the explanation of the Bavarian method of fermentation will afford a clearer illustration of the matter than that adverted to. In gyles, generally speaking, the proportion of gluten, with reference to its utility in producing yeast or assisting in the fermentation, is greater than that of the sugar to its requirements in the formation of spirit and giving *fulness* to the drink; and although much of this excess may be removed by the boiling, still, after the usual process of attenuation has been effected by the generality of brewers in this country, a very considerable quantity of glutinous substance remains dissolved, and it is this that exposes the liquors to so much danger of spoiling, whereas, if it were removed, no apprehension of decomposition need be entertained. The process of fermentation, as carried out in Bavaria, is simply such as will entirely remove this excess of nitrogenous matter in the worts, and leave the beer consisting of no other constituents but water, alcohol, sugar, and the conserving principle of the hop.

The course adopted is the following:—After the worts are boiled and hopped, they are spread out upon large shallow pans, in an atmosphere of from 45° to 50° Fahr., under ground, and the fermentation is allowed to proceed spontaneously in contact with the air, the heat of the liquor being restricted within the above limits. In three to six weeks, as the case may be, the attenuation is completed; but during this period the evolution of carbonic acid, and the formation of a barmy head, as in the fermentation already described, are quite different from what is observed in this country. Carbonic acid is indeed evolved, but only in minute globules, such as pass off from a liquid saturated with it at a high pressure; and as to the formation of a head of yeast, the surface is scarcely covered with a scum, so completely is the ferment precipitated to the bottom of the liquor in the form of a viscous slime. The material difference of the precipitated yeast in the Bavarian course of fermentation, and that which rises to the surface in the rapid process is, that the first is the result of a slow oxidation of the gluten, termed decay, or eremacausis; while, in the second instance, it proceeds from a destruction of the equilibrium existing between the particles of the compounds present in the worts, independently of the action of the air, and to this change the term *putrefaction* has been applied. Yeast produced by decay, or the slow absorption of oxygen, does not excite the putrefactive, but the decaying fermentation in a wort; while, if yeast or any analogous body undergoing the putrefactive state of decomposition be added, and the action it induces be restricted under a temperature of 50° Fahr., then, although the newly-formed yeast will occasion the putrefactive change in a fresh wort, yet, when the same operation is repeated several times in succession, that process, by which only the precipitated yeast is formed, takes place, and the deposited matter has lost the power of inducing the ordinary fermentation even at a moderately elevated temperature. This matter is capable, however, of causing a very protracted internal action in the sugar, whereby it is split into carbonic acid and alcohol without affecting in the slightest degree the gluten which may be held in solution. The contact of the already decayed gluten is necessary to induce a corresponding action in that held in solution, as well as to transform the sugar into alcohol and carbonic acid, and, after this, exposure to atmospheric air is indispensable; for if the latter be excluded, the further change in the materials of the gyle is entirely arrested in regard to the precipitation of the nitrogenous products. Were these conditions accompanied with a high temperature, the aim of the brewer would be frustrated; for the alcohol, as well as the gluten, would then undergo an eremacausis or oxidation, and the resulting product would be vinegar; but at the very low degree at which the Bavarians conduct the process, the alcohol is incapable of oxidation; meanwhile the gluten readily enters into combination with it, and precipitates.

With reference to the question whether the gluten assimilates oxygen from the air, or whether it takes it from the sugar or water, or by a decomposition of its own particles unites with the oxygen—this is a subject upon which much has been said, and in some cases the explanations are still mysterious and unsatisfactory. It is well known that in the slow fermentation in question, if the air were excluded the action would cease; but that the decomposition of the saccharum into alcohol and carbonic acid does not require air, and hence it must be taken up by the gluten; yet, whether it is directly combined with the other elements of this body, or whether it abstracts hydrogen from it, is another question no less intricate than the former. A chemical analysis would not be decisive on this point for many reasons known to chemists, analogies of which are numerous in the range of organic bodies, such as colorless and blue indigo. DUMAS found that the colorless body differed only in one equivalent of hydrogen from the blue variety; but whether the latter is simply the former united to oxygen, or whether the colorless compound is a hydride of the blue substance, is a matter difficult to decide; and, in the same manner, it is a question whether the precipitated decayed gluten is a combination with oxygen, or that the latter has abstracted hydrogen and formed water, leaving the insoluble substance. In the course of rapid fermentation, the same oxidation of the gluten must take place as in the slow process, except that it is not so thoroughly completed as in the latter case; and since the fermentation in the former is carried on out of contact with the air, it follows that the oxygen necessary either to dehydrate or oxidize the gluten, must be derived from some compound in the liquor. That water is decomposed is almost impossible, for the oxygen in water is held more powerfully in combination than it could possibly be in the new arrangement of the oxidized gluten; besides, it is well known that when organic complex substances undergo decomposition, the elements of such always resolve themselves into more permanent and simpler bodies. There remains, therefore, only one substance which, by its decomposition, affords oxygen, and that is the sugar.

In close fermenting tuns, the amount of yeast or ferment thrown off is in proportion to the quantity of sweet principle that enters into another species of decomposition, besides that which generates alcohol and carbonic acid; and hence it follows, that the entire weight of sugar is not changed into spirit in close fermentations, whereas, on the Bavarian principle, the whole, even to the last grain, may be converted into alcohol and the other products of the vinous fermentation. From what has been said upon this subject and its principles, the reader will readily discern the difference between the Bavarian beers, and those made in England and Scotland from malt and hops; in the latter, some gluten always remains, which, by a slow internal species of putrefactive oxidation, and at the high temperatures that usually pervade the atmosphere in summer weather, occasions the further eremacausis or oxidation of the alcohol into acetic acid; whereas, with the former, the case is different, because the whole of the nitrogenous matters are completely deposited on the fermenting floors, and being thus thoroughly purified from such substances as tend to cause a fresh fermentation, the liquor when racked is secure against decomposition, notwithstanding that it may have been exposed to 70° or 80° Fahr.

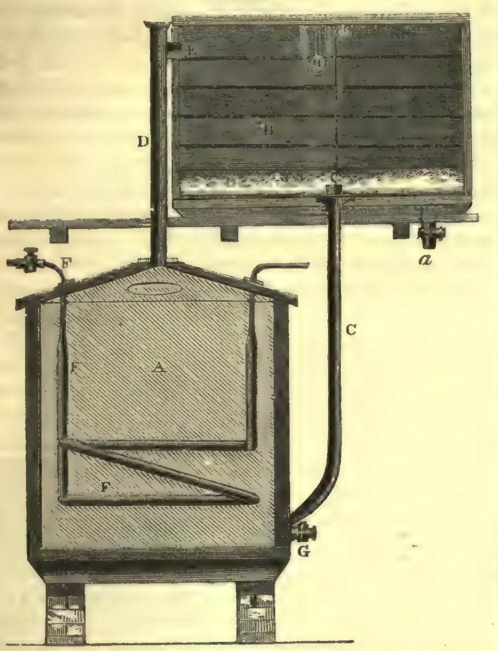
Among the home improvements, the first which was brought to the brewer's aid was the attemperator; this apparatus consists of a coil of metallic tubing placed in the tun, and through which cold water circulates, in order to lower the temperature of the gyle when, from the force of the internal action, it rises too high. This apparatus is now universally employed, and greatly contributes to insure the success of the operation.

The double fermenting square is another of those contrivances which have acquired some celebrity in Yorkshire and the adjoining counties. It consists of an inner close square, with an exit pipe from the cover, through which the barm escapes. In this the worts are inoculated with the ferment, and the space between its walls and those of the exterior square is filled with cold water, by which the temperature of the enclosed liquor is maintained at a low point, and hence the fermentation, though slow, is more sure in its effects. It is controlled, however, with much difficulty, unless there is sufficient spring water at command, especially in summer weather, when cistern or surface water acquires a heat of between 60° and 70° Fahr. The brewer's main endeavor is to keep the fermentation at about 62° to 64°, till the attenuation has been continued as far as is desirable; then, by transmitting cold water into the exterior chamber, as well as through an attemperating pipe placed in the liquor, the heat is reduced to about 56°, at which degree it is maintained during the cleansing.

HARVIE'S patent is another contribution towards the improvement of the fermentation; its great peculiarity is, that it executes its work in close vessels, in addition to which any other compound composed of carbonic acid, and a base such as carbonate of soda, *et cetera*, may be prepared by transmitting the evoluted gas through a solution of the alkali made for the purpose. The apparatus consists of four tuns or covered vessels, connected together by pipes fixed air-tight in the covers, and passing into the liquor from one to another, similar to the plan of WOULFE'S apparatus, till, finally, the carbonic acid is transmitted through the solution in the fourth tun, which requires to be saturated with it. The covers may also be taken off at will, and there are orifices for the purpose of admitting the gyle and other ingredients, but these are closed during the fermenting action. When the attenuation is finished, the contents may be drawn off through openings for that purpose near the bottom. During the fermentation, the liquor should not be allowed to pass from one tun to another; and hence the internal action must be subdued by a reduced heat, so as to discharge the whole of the carbonic acid slowly into the fourth tun.

The annexed simple arrangement represents the patent fermenting square of Messrs. WALKER and SON, the leading brewers of Warrington, Lancashire, an arrangement which, in the Editor's opinion, answers every expectation in reference to a good fermentation. It consists of two squares, both air-tight; one, A, in which the fermentation is carried on, and the other, B, for collecting the discharged yeast. Both are connected by a pipe, C, which descends from the bottom of B and enters A at the front near the base. Through this pipe the gyle, as well as the yeast, is admitted into the square, completely filling it; then well-fermented ale is poured in, till there is a layer about two inches in depth on the bottom of the yeast-receiver. As soon as the fermentation commences, and the yeast, as yet frothy and partially formed, begins to be discharged, it rises through the pipe, D, issuing from the top of the bevelled cover, and is discharged into the yeast-receiver at E. As the semifluid matter comes off from the lower, the layer of beer in the yeast-receiver descends in its stead, and maintains the proper level, leaving the bottom of the latter by the liquor received from the lower tun, still covered to the depth of one or two inches, and preventing the froth from again passing into it. In this way the operation is conducted till finished. Should the heat of the liquor be too high, it may be controlled by the transmission of cold water through the attemperating pipe, F. Another cylinder, H, through which a stream of cold water is passed, keeps the air in the covered yeast-receiver sufficiently reduced, thereby arresting the carbonic acid gas arising from the action of the fermentation, which, by any other methods in use, in a great measure escapes. This, to all who are conversant with the subject, is known to be very valuable in securing the soundness of the beer, and giving it a tone of warmth, besides rendering it pleasant and agreeable to the palate.

Fig. 164.



At the termination of the fermentation, the yeast which is accumulated entirely in the square, B, is collected by drawing off the layer of liquor which covers the bottom of this vessel, by means of a hose attached to a pipe, seen at *a;* and when this is done, the barm is brushed out through a plug-hole near one of the corners, and passed along a hose into proper vessels. Should the yeast accumulate in great abundance in consequence of an excess of gluten in the gyle, then, by the same course as the preceding, it may be swept out, and the ale drawn off, pumped up once more, and the fermentation continued till finished.

The heat of the fermenting liquor is under complete control, and may be retained at any degree, provided well-water is at hand; but even if this could not be obtained, the heat of the square would not become so elevated as in the ordinary vessels, because, the froth being removed, the decomposition of the sugar is carried on by the equilibrium of its atomic constituents being destroyed in the first instance, and then it continues, notwithstanding that apparently no formed yeast remains in the gyle. From a personal inspection of the method of Messrs. WALKER, the Editor thinks its introduction into general use would be of great benefit to brewers, for not only does it dispense with the necessity of watching and hand labor required in the usual system, saving an immense amount of space in fermenting a large quantity, on account of the compactness of the apparatus, but the brewer can obtain any attenuation he requires, independent of weather or other circumstances; and at its close, the liquor, after being cooled by means of the attemperating pipe, F, is ready to be drawn off through the tap, G, into barrels or hogsheads and sent to the consumers, in consequence of the yeast being removed during the operation. Messrs. WALKER use twelve ounces of barm to each barrel of wort.

Another great advantage of this system, and one which is entirely overlooked in the other methods, is found in the fact, that no such taint as *yeast-bite* can be discerned in the liquor.

Having thus enumerated the principal methods of inducing and regulating the fermentation, the next process in brewing is now entered upon, namely—

THE CLEANSING, which seems to be followed universally wherever patent fermenting utensils, such as those last described, have not been employed. After the fermentation in the tun has flagged, and the chief portion of the yeast has been removed by skimming or otherwise, particles of yeast and glutinous matters still remain held in mechanical suspension in the body of the beverage, and giving it a muddy appearance. Could these be even removed by filtration, the liquid would still appear muddy, since the fermentation has not completely ceased; and as long as this lasts, fresh particles of yeast will be generated, and these will keep the liquor turbid and impure, unless checked in due time. The ordinary practice is to rack off the contents of the tuns into smaller vessels, ranged horizontally, with a bung or orifice open for the egress of solid matter brought up by the gradual development of carbonic acid from the interior; the vessels are kept full with fresh liquor—generally well-fermented ale. In this way the work is carried on till the fermentation entirely subsides, and the ale becomes completely freed from any floating yeasty matter. As the barm rises to the bung-hole, it falls into a trough which conducts it along to a yeast tub, or receiver. The cleansing, when properly performed, is a very important stage; the distribution of the attenuated liquid into small portions has the effect of reducing the fermenting action considerably—so much so, that if the attenuation has not been sufficiently advanced at the time of racking off into the cleansing vessels, very little can be effected in them, and the liquor will remain too sweet. To prevent this, many brewers either briskly agitate the contents of the fermenting square, to raise the yeast which may have been deposited on the bottom, or add a fresh quantity of the ferment to it, and rummage the whole with an apparatus fitted in the tun for the purpose, or by any other contrivance. In either case, the object is to give the ferment a fresh stimulus, in order to counteract in some degree the checking influence of the racking into small quantities, whereby the temperature and other conditions that aid in converting the sugar into alcohol are not a little reduced.

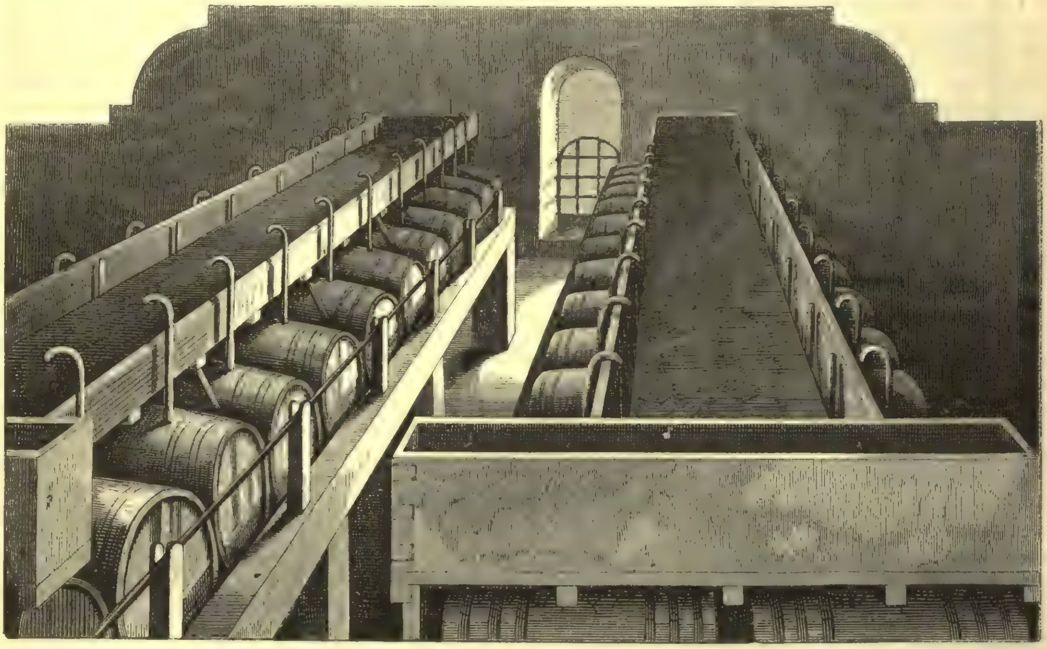
It would, however, be preferable to push the fermentation so far in the tun, as that only enough of saccharine matter will remain to give to the liquor sufficient body, and also, by its slow fermentation, develop so much carbonic acid as to keep it sparkling and refreshing.

In the extensive breweries of Messrs. BASS and ALLSOPP, the cleansing is very effectually performed, and for this reason a description of their method will here be given. As already stated, the cleansing has for its object the arresting of the fermentation, and the separation of the yeast, by being transferred into smaller vessels, where it remains for a longer or shorter time, till the clarification is complete. At the above firms there is a number of casks, amounting to 800 or 900, all of which are placed in the cleansing-room for the purpose of depurating the ale. Each of these casks is capable of holding four to five barrels. About ten or twelve of them are suspended on a substantial frame, so as to admit of a free revolution of the casks on their axis. Above these, a large wide open trough—the yeast trough—is placed, with which each of the casks beneath communicates, first, by a movable or sliding tube, and secondly, by a head pipe, usually called a *swan-neck;* the former connection can be cut off at pleasure by a wooden plug. Diametrically opposite these two outlets, a tap is screwed into the casks, and through this the liquor is drawn off when ready for racking. Immediately below these taps, another trough is erected along the whole range, and the liquor is by this means conducted into the racking squares. At one end of the superior trough there is a small reservoir, capable of holding five or six barrels of liquor, and called the *feeder*, in consequence of its being connected with each of the casks by a small pipe running parallel with their ends, and branching off into each; by this means the liquor which separates by evaporation, and also the yeast, are replaced from the reservoir.

Fig. 165 more fully explains this arrangement.

The following is the method of working the apparatus:—The ale to be cleansed is pumped into the large yeast trough, and then run into the casks through the sliding tubes; when the cask is quite full, this communication is stopped up with the wooden plug mentioned before, leaving only the swan-neck outlet free. Through this pipe the froth arising from the fermentation forces its way, and is transferred to the yeast trough, where the yeast is deposited in a manner somewhat similar to the apparatus of WALKER, noticed in the preceding.

Fig. 165.



To keep the casks full, and to enable the froth to rise to the yeast tun, a quantity of liquor is put into the reservoir, and thence conducted into the casks by the pipe already mentioned. After the fermentation has continued in this state for one or two days, it apparently subsides altogether; the contents are then permitted to remain at rest for a few days longer, for the purpose of affording any yeast that may not have ascended to the trough, time to precipitate to the bottom. The clear ale is then drawn off by means of the screw tap inserted in the lower part of the casks. By turning this tap the interior sucker is so far elevated as to be above the dregs, and therefore none of the impurities are carried off in the liquor, but remain in the casks.

It often happens that the yeasty matter or grounds disseminated through the ale in the casks, does not precipitate, and the consequence is, that it causes the muddiness already noticed to remain. It appears that the composition of the water has a very great influence upon the cleansing of the ale, for when lime compounds are present, the action of the salts inherent in the malt and dissolved in the worts, causes a double decomposition, by which a lime salt is precipitated, and this carries with it the impurities to be removed. The Burton water, as shown at page 244, is remarkable for its adaptation to brewing in this particular, namely, that no finings or other extraneous matters need be added to the fermented menstruum, in order to produce a clear transparent beverage. In a great many instances, where recourse is had to the use of finings, a little more care bestowed upon the preceding operations would do away with the necessity of using them, and it is very questionable whether, in any case, finings or precipitating agents for removing the impurities should be employed.

The substance most generally used for this purpose is isinglass, which is dissolved in sour beer, and then strained through a hair sieve. The consistence of this solution is that of pretty thick mucilage. When a small quantity of it is poured into a cask of the ale or beer, the grounds separate in a very short time, and the liquor remains bright, and free from mechanical impurities.

With respect to the action of the fining liquor on the ale, no very satisfactory explanation can be given Many regard it as spreading over the surface of the menstruum, and forming, as it were, a network, which envelops the whole of the mechanically suspended matters, and carries them with it to the bottom, while the supernatant liquor remains clear; others, again, look upon the floating impurity as being held by the cohesive attraction of the surrounding fluid, in such a condition that, whilst the affinity of the latter is not so powerful as to cause solution, it is nevertheless so strong as to keep it suspended, or in combination; and the fining is supposed to operate, rendering the affinity of the solution for the grounds less, in consequence of being itself dissolved, while it is affirmed that the least derangement of this power is sufficient to insure their subsidence; while some think that, from the fining being lighter, it immediately ascends, carrying with it the deteriorating ingredient, leaving the beer in a clear state. It is evident, however, that there must be a combination of the yeasty matter with the isinglass—whether of a mechanical or chemical nature is not ascertained—it may be a conjunction of both. This is more obvious from the circumstance, that other substances, such as glue, which seemingly partake of the same properties, will not effect a depuration. It would seem also, that the great divisibility of the matter in the beverage, together with a more or less cohesive affinity of the liquid for it, is the cause of its retention; and if this cohesion be in some measure destroyed, by either precipitating the substance, or bringing the particles closer together, so that they may combine from the effect of the attraction among themselves, the liquid will then readily clarify.

Many other bodies, such as albumen of eggs, or serum of blood, react on muddy ale, like isinglass. **Donovan** states that *alum*, in the proportion of one ounce to the hogshead, will purify it thoroughly in a very short time, and without leaving any perceptible taste; he further says, that the dried stomach of the cod-fish, called *sounds*, on being macerated in sour beer, affords a fining liquid equal in most respects to the more expensive isinglass. To dissolve the sounds perfectly, eight or ten days are required, and nothing remains but a small quantity of impurities, which straining through a cloth filter will remove. More or less of this solution will be required, according to the purity of the liquor; but it is certain that, *ceteris paribus*, the less either of this or of isinglass liquid that is used the better, for these substances tend to communicate a flat taste to the product, and prevent it from carrying a good head. When sounds are used, it is better to employ them in summer than in winter; in the latter season, isinglass is to be preferred.

Very many persons, after the fermentation has ceased, instead of cleansing in the way above mentioned, add a fresh quantity of hops, and leave them in contact with the liquor till the whole of the yeasty substance is carried down with them as they subside. The ale, in this case, is improved to some extent by the addition of the fresh hops; but where the custom is to introduce some of the spent hops from a previous operation, the practice is productive of more injury than benefit.

After the clarification, the ale is racked off into store vats, or barrels, to be sent to the consumers; and in doing so, much attention must be directed to the casks and vessels, in observing that they are wholly free from any putrid matter, or bad taste or smell, which would contaminate the ale. The washing of barrels, hogsheads, *et cetera*, is frequently a work of great trouble to many brewers, when the ordinary course is followed. **Davison**, **Symington**, **Payne**, and others, have taken out patents for preserving wood, cleansing casks, and so forth, which, to all appearance, are well worth the brewer's attention, but which require too much detail, and are of too mechanical a nature, to be further noticed.

Having thus far given a general view of brewing, and the various causes which affect its success, a few words will now be added on the preparation of particular beverages, and first among these will be noticed—

PALE ALE.—Pale or East India ale is nothing more than beer made from worts extracted from the palest malt, and boiled with the palest and best hops. Every attention is given to the selection of these materials, in order to insure the pale color peculiar to this ale. A great deal of East India pale ale is now used at home, but it differs from that exported, inasmuch as it is less bitter and more spiritous—in every other particular of manufacture and composition they are alike.

The only localities where this excellent beverage is produced in large quantities, are Burton, London, Glasgow, and Leeds. In the latter place, a very large quantity of East India pale ale has for some years been brewed by Messrs. **Tetley and Son**; and Messrs. J. and R. **Tennent**, of Wellpark Brewery, in Glasgow—one of the oldest and most extensive establishments in Scotland—also prepare pale ale for exportation both to the East and West Indies, commanding in the markets of the latter a large sale.

The peculiar excellence of the ales of the Messrs. **Tennent** and Messrs. **Tetley**, like those of Burton—both of the latter of which were analysed by the Editor, as also the waters used in their preparation—

is their remarkable keeping quality, and their retention of that delicate flavor of the hops so often lost by the pale ale brewer, notwithstanding his utmost efforts to secure it. This, of course, arises from the near approach made in their practice to the theory, that a low fermenting heat can alone preserve the beer from the simultaneous formation of acetic acid with the alcohol, and their recognition of the fact that 72° Fahr. is the highest degree of heat that can be safely depended upon. Brewing, it is well known, has been long carried on in Bavaria on these principles; but hitherto there has existed an insuperable objection to their adoption by the more extensive firms of this country, on account of the great length of time required for perfect attenuation. This difficulty, however, would appear to be at length overcome, the fermentations being now finished in as short a time as by the old mode; the hop flavor is also preserved, and indeed it may be safely asserted that its delicate aroma is never more surely destroyed than by a high and turbulent fermentation.

This new process of brewing pale ale has also the advantage of affording greater purity of fragrance, it being well known that the dissolution of barm by alcohol, the result of which may often be detected in the yeasty flavor of ale, is much accelerated by high temperatures. Good water, as previously stated, is indispensable in a brewery, for sound ale cannot be brewed with water not adapted for the purpose. The water at the brewery of Messrs. **Tetley** is similar in constitution to the Burton water, as will be seen on referring to the analysis of it, by the Editor, at page 245. That used at Wellpark by the Messrs. **Tennent** has been analysed by Dr. **Penny**, and found to contain the following matters:—

	Grains in the imperial gallon, or 70,000 grains.
Sulphate of lime,	7·2
Sulphate of magnesia,	1·5
Alkaline sulphates,	8·7
Carbonate of lime and magnesia,	8·0
Chloride of sodium,	2·4
Oxide of iron,	·1
Siliceous matter,	·7
Organic matters,	·3
	28·9

Some very excellent bitter ale is now brewed in Birkenhead, near Liverpool, by Messrs. **Cook, Brothers**, who kindly conducted the Editor through their well-regulated establishment—a visit from which he derived many good practical hints. Some of the ales they manufacture, especially those at their Neston works, are very similar to the Burton. The Editor believes that the secret of this superior product is chiefly to be found in the composition of the water, which he analysed with some care, and found to contain large quantities of earthy carbonates and sulphate of lime, without *any organic matter*, which, when existing to any amount, is decidedly deleterious.

Repeated allusions have been made to the methods pursued in different pale ale establishments, in the various stages of mashing, boiling, cooling, *et cetera*, already explained, and, therefore, a recapitulation of these is unnecessary.

The only particular which requires to be noted, in addition to what has been already said, relates to the use of the hops, which, in making this beverage, are added in larger quantity than for the manufacture of the common ales. **Roberts** states that the proportion of hops varies from twenty to twenty-two pounds per quarter of malt; but, considering that the density of the worts is not so high as in many other instances, being about 1·055 specific gravity or upwards, the above proportion must in the majority of cases be very considerably more than the brewers of the present day employ. About sixteen pounds per quarter may be taken as the average allowance, but more or less within certain limits may be used—according to the special object of the brewer—in making a richer beverage, or inoculating the ale with a larger proportion of the bitter ingredient. Considerable care is exercised by the pale ale manufacturers, in having the worts well boiled with the very best hops, so that all the valuable constituents of the flowers may be taken up in the gyle; hence, it is not unfrequent among the Burton brewers to continue the boiling for a period of two hours and a half or three hours. The cooling and pitching heat of the gyle are the same as have been described; and the fermentation and subsequent cleaning have also been fully explained. As, however, the routine and materials employed might affect the fermentation, it may be well to offer a few observations upon this subject.

In making pale ales, the fermentation should be restricted within the range of 60° to 68° or 72° Fahr., according to the degree of heat at the pitching, and the state of the weather. From the beginning of the attenuation, till about three-fourths of the sugar are converted into alcohol, nothing further is required than to observe that the heat is gradually progressing in proportion to the attenuation. After this, greater vigilance must be observed in skimming off the yeast, and checking the action of the ferment, so that the further decomposition of the remaining portion of the sugar may take place at a declining temperature, during which the cleansing can be thoroughly executed.

When this is finished, and the clarified liquor is racked off, it is customary to allow it to rest for eighteen or twenty hours, in order that it may become more clear. It is then run into the casks, barrels, or hogsheads, as the case may be, which, when filled up to the bung, are shived or bunged tightly, and conveyed to the stores or consumers.

It is of great importance that the ale should commence a slow progressive fermentation in the cask, to retain its sparkling and brisk qualities; and to insure this, so much saccharine matter must be left in the liquor, as will, by its conversion into alcohol and carbonic acid, communicate and keep up the requisite briskness; otherwise, if all the sugar were fermented in the first instance, and nothing left to develop the carbonic acid afterwards, the beer would be characterized as flat; while, if it retained nitrogenous matters, and were conveyed to hot climates, it would in a short time become acid and putrefy.

Much of the success of the pale ale manufacture depends upon the care that is taken in selecting the best materials for its composition. It must also be understood, that the several operations through which the malt and hops have to pass, as described in the preceding pages, must be performed with great attention, so as to preserve the color, taste, and other properties of the ale in their fulness and purity.

In the immense establishments at Burton-on-Trent, especially those of BASS and ALLSOPP, where each process is under the strictest surveillance, it is really beautiful to remark how much caution and precision are exercised in every department; it is owing to this, collaterally with the qualities of the water, that the Burton ales have been rendered so justly popular as beverages, and so highly recommended by physicians for their tonic properties.

SCOTCH ALES.—These ales were at one time in considerable repute, possessing a peculiar sweetness not noticed in other beverages. This—especially as regards the Alloa ales—was owing to the addition of Russian honey to the liquor, a practice which has now been abandoned for many years. It is customary with the Scotch brewers to distinguish the quality of their ales by the price; thus, there are three guinea, four guinea, six guinea, and so on to ten and twelve guinea ales, but the latter are rarely brewed. The routine of mashing is mostly the same in Scotland as that usually followed by English brewers. The principal points of difference will appear from the annexed particulars gleaned from one of the most intelligent, expert, and extensive brewers in Scotland.

The density of the wort depends, of course, upon the quality of the ale to be produced. The following are the densities adapted to the different qualities, reckoning by ALLAN'S saccharometer:—

For 3	guinea ale	the density is about	......	65°
" 4	"	"	......	80
" 5	"	"	......	95
" 6	"	"	.....	108
" 8	"	"	......	115
" 10	"	"	......	125

In preparing the worts of four guinea ale, two barrels of water at 175° Fahr. are generally taken per quarter of malt and mashed; this is then sparged over with two and a half barrels of water at 190°. For the other varieties the same amount of water is taken for the mash, but the quantity used in the sparging is less in proportion to the density which the product has to indicate; thus, for five guinea ale, the sparging is made with two barrels, and with one and a half for six guinea ale, whilst the spargings are not added at all in preparing the richer ales. Properly speaking, only one wort is drawn in Scotland, but the lengths of sparging, as just shown, make up for the after worts of the English brewer.

The hopping and boiling of the worts likewise vary but little from the practice already pointed out:—

4 to 5 pounds of hops per quarter are used for 4 guinea ale;
5 " 6 " " " 5 "
6 " 7 " " " 6 "

and so on; the period of boiling is from one to one hour and a half with the better class of ales, but is prolonged to two hours, or longer, when the product is poor. The criterion in this, as well as in those instances already alluded to, is the breaking of the flocculent matter, which the attendant carefully watches, and tests occasionally by taking samples in a small vessel, and observing if the flocks readily precipitate. The cooling is performed in the usual way. The pitching heat is about 57°, though sometimes it is reduced to 56° or even 54°; and the period of attenuation extends from eight to twelve days, according to the weather, during which the heat rises to about 70° or more, but never higher if possible than 72°. The extent of the attenuation varies from half to two-thirds of the original gravity. The cleansing of Scotch ales differs in nothing important from the usual system. It may be stated, however, that in Scotland the attenuation is finished in the fermenting tun.

The practice of adding flavorings in the shape of berries, *et cetera*, is now entirely discontinued in Scotland, at least among the more respectable brewers.

PORTER.—Previous to the year 1730, the malt liquors principally drunk in London were ale, beer, and twopenny, and it was usual for the customers to call for half-and-half, that is, half ale and half beer; half ale and half twopenny, or half of beer and half of twopenny. In course of time it also became the practice to ask for a pint or tankard of *three threads*, signifying a third of ale, of beer, and of twopenny; and thus the publican had the trouble of going to three casks to get the mixture required. To avoid this, a brewer conceived the idea of making a liquor which should unite the flavors of the three; he did so, and called it *entire*, and as it was a hearty beverage, it was very suitable for porters and other workpeople—hence the name, *porter*.

The manufacture of this beverage constitutes a large and profitable branch of the brewing business, especially in the metropolitan cities. London and Dublin porter stand foremost in point of quality, but even in these some very inferior samples are to be found.

Considerable disparity of working exists in the various porter breweries throughout the kingdom, which arises from many circumstances, such as the taste of the consumers, the nature of the climate, and such like. In theory, however, the work differs little from the course laid down for brewing ale, but, for the instruction of the general reader, such variations as do exist will be briefly pointed out.

As in the case of pale ale, the great difference in porter from common ale, is the variety of materials worked upon. The grist employed by the porter brewer is composed of various species of malt, mixed together in different proportions.

The annexed table gives a view of these mixtures:—

TABLE OF PORTER GRISTS.

No.	Black.	Brown.	Amber.	Pale.	Total.
1	9	0	0	91	100
2	6	34	0	60	100
3	2	30	10	58	100
4	3	25	15	57	100
5	4	24	24	48	100
6	5	0	95	0	100

Of these, preference is given to the last two, as being the fittest for preparing a good porter; in the others, the excess of black and brown malt occasions too much carbonaceous and useless matter in them, from which the porter acquires a disagreeable taste, as if liquorice and similar compounds were mixed with it.

The malt, on being subjected to a high temperature during the drying, undergoes a decomposition, by which the farinaceous portions are deprived of their natural properties, and converted into a more or less charred mucilaginous substance, according to the degree of heat communicated.

In the amber malt, although some slight carbonization has taken place, yet it is not so powerful as to prevent the saccharification of any considerable portions of the starch, and therefore, while the wort prepared from this is much more colored than it would be if obtained from pale malt, the sacrifice of valuable matter is not very great; as, however, the color given to the mash is not so dark as the consumers require, the quantity of black or patent malt is employed to communicate this shade. The amount of the patent malt varies according to the skill of the manager, and the quality of the remaining portion of the grist.

As in the preparation of pale ales, so in porter breweries, strict attention must be paid to the qualities of the materials.

In preparing the worts, generally a stiff mash is made, and after an hour's maceration, a further portion of water at a high temperature is added, making a total of about three barrels of water per quarter of grist. The whole is mashed for a short time after the second addition, and then the tun is covered till the time of racking, which generally happens in an hour or an hour-and-a-half's time. The worts are pumped into the copper, and boiled and hopped in the usual way. The quantity of hops varies with the quality of the porter to be produced, and according as it is, or is not, intended for exportation, so that the manufacturer must be left to the exercise of his discretion. Among the porter brewers, the proportion extends from six to sixteen, or twenty pounds per quarter. The usual period of boiling is an hour and a half; meanwhile the grist is being further exhausted by the addition of more water, so as to have the second wort ready by the time the contents of the copper are turned into the hop-back.

The hops used in the first boil, and which are not entirely deprived of their virtue, are in many establishments returned to the copper with the second wort, the whole retained at the temperature of ebullition for two hours, and then discharged to the hop-back, from which the gyle flows off, and is cooled down afterwards previous to fermentation.

Before proceeding further, it may be well to make a short allusion to the temperatures at which the mashings are performed. In consequence of the slight degree in which the malt is carbonized or decomposed, the tendency to set or form a coagulum is not so great as when pale malt is macerated in the water, and therefore the temperature of the liquor may be to some extent higher than if the pale malt were operated upon. The reverse of this was supposed to have been the case for a long time, but the truth was at length elicited. Nevertheless, when the large proportion of pale or amber malt is used, the brewers content themselves with the application of water at 160° or 165° for the first mash, and in the second, the liquor has a temperature of 170° to 180°. These heats are subject to a variation of 5° or more, according to the judgment of the manager, and the composition of the grist.

Porter gyle, after being cooled, has usually a specific gravity of 1·052 to 1·081, varying with the intended price of the beer. The fermentation of porter gyle should be vigorously carried on, till the attenuation has advanced to about two-thirds the original gravity; this will take place, according to circumstances, in from two to four days, the temperature rising from 10° to 15°. As soon as it is observed that the heat remains stationary, the preparation for racking off the beer to the *rounds* for the purpose of cleansing is entered upon. Here the barm is discharged and collected in a proper recipient, either by the use of such an apparatus as that at BASS or ALLSOPP'S, noted on a previous occasion, or by the ordinary method. As soon as the sensible fermentation has ended in the rounds, the beer is either pumped into large open receivers, where it deposits a considerable quantity of the *lies* or *grounds*, or is sent to the store vats to be matured.

Such is the usual routine for the preparation of porter, but much more is necessary, or is at least deemed so, subsequent to these operations, in order to make the porter suitable to the different markets for which it is destined, but reference will be made to this afterwards. When the beer does not clarify spontaneously, isinglass is generally applied as a fining agent. Porter intended for keeping or for shipment to warm climates, requires to be as free as possible from any dregs or yeasty matter, and well seasoned. Nothing will assist the brewer in this particular so much as the choice of the best materials.

Good porter has generally the following characteristics:—It is perfectly bright, dark-colored, brisk or well impregnated with carbonic acid; light; sufficiently bitter to the taste; and free from too much acidity.

According to the opinion of several in the trade, the Excise regulations, as at present existing, depress their operations very much, in consequence of the duty being levied upon the malt, on the assumption that it will yield four barrels of beer of 19·4 pounds per barrel, or specific gravity 1·054.

Laying down eighty-four pounds as the maximum yield of a quarter of porter grist, this amount cannot be far from the truth, and according to many brewers the produce is more frequently eighty pounds than otherwise; indeed, considering the loss in boiling, hopping, and fermenting, it is evident that the forementioned produce cannot be fully obtained. No drawback is allowed by the Excise upon the difference of the quantity upon which duty is levied, and that actually obtained; hence it is very evident that the manufacturer suffers.

Mr. CROCKFORD of Long Acre has recently patented a machine for mashing, which he denominates *the Archimedean Attemperator*.

The improvements involve but a small outlay, as they can be readily adapted to the mash-tuns—with or without machines—already in use, and may be worked by either steam, horse, or manual power.

The advantages to be derived from the attemperator are as follow:—

1. The great precision with which the heat can be regulated, whereby every part of the mash can be kept at the same temperature, and this condition prolonged for an indefinite period.

2. The wort can be made to circulate constantly

through the grain, effectually removing the saccharine matter as it is formed, and at the termination of the process it becomes perfectly bright.

3. The apparatus is said to be incapable of derangement, of great durability, is free from valves, *et cetera*, is easily constructed, and no part of the heating apparatus comes in contact with the grain.

4. The extract obtained by the Archimedean process affords a considerable increase over that produced by the present system.

Besides these benefits, the time of brewing is reduced one-half, and much less liquor is required to obtain the whole extract, than by the methods at present in use.

The machine has hitherto given the greatest satisfaction at the breweries where it has been employed.

ADULTERATION OF BEERS.—This subject, fortunately, is not so difficult to deal with at the present day, as it was about half a century ago; whether this result is owing to the increased morality of the brewer, or to the vigorous measures taken by Government in detecting and punishing sophisticators, is a difficult point to determine; but certain it is, that the ingredients which are said to have been employed at that time are positively frightful to contemplate.

The causes of such adulteration might, with truth, be said to originate with the consumers, some fancying a pale liquor, whilst others prefer an amber or brown.

At one time the close approximation of the color to black, was imagined to be a sure sign of perfection.

To communicate such a shade, and at the same time evade the duty payable upon the malt, many resources were tried, such as the use of caramel, or treacle boiled down to blackness; elder-berries, Spanish juice, *et cetera;* and these continued to be used for a considerable period. Caramel, or burnt sugar, and liquorice, are said to be employed at the present day, notwithstanding that all these adulterations are strictly prohibited by law, under a heavy penalty. In the other departments of the manufacture, especially in the means employed for preventing acidity, raising of a creamy head, and giving a semblance of age to the product, many brewers have recourse to such substances as *salt of steel*, or sulphate of iron, chalk, or other earthy carbonates or alkalies.

When the beverage is made from good materials, and with proper care in the fermentation, it remains sufficiently viscid from the gummy matter and sugar in solution, so that, in pouring it from one vessel to another, it gathers on its surface a close creamy foam or head, which, when blown aside, readily closes again. This is more particularly the case with good porter; but when the body or unfermented matter of the beverage is in small or insufficient quantity, this does not take place, and the bad quality of the liquor is thus detected by the consumer.

In order to conceal this inferiority, and give an appearance of richness, the brewer very often, but the vender repeatedly, adds more or less of *heading stuff*, made of isinglass and sour ale beaten well together, introducing a small quantity of this with an ounce or two of sulphate of iron into each hogshead. This has the effect of raising a froth upon the liquid, and also of making it to close immediately when blown aside. By the use of chalk, beer which has become sour may be deprived of its acidity, but it will never be palatable after such treatment, especially if the quantity of acid in it is rather large. When such happens, especially in the porter establishments, the practice is to mix the sour with fresh-brewed beer, and send it to the consumers at once as old porter. Many other ingredients are said to be mixed with beer, particularly by retailers, whereby the bitterness, the stupefying properties of the liquor, and even the thirst of the consumer, is increased, but such adulterations have not come within the range of the Editor's experience. It is asserted, however, that even in breweries, many herbs and seeds, such as wormwood, India berry, or *cocculus indicus*, the fruit of the *Picrotoxia*, or *Menispermum cocculus*, a plant containing an active poisonous principle, *picrotoxin*, and various others, are employed to impart bitterness. Of the articles used to mix with beer, many are harmless; while others, as cocculus indicus, *et cetera*, are highly injurious.

ANALYSIS OF BEER.—This is of much importance to the brewer and toxicologist; to the first, it becomes a means whereby he learns the composition of the worts or gyle of his neighbor, and his precise method of operation; to the second, it is of great consequence, as it detects the poisons administered in malt liquor, by means of which many dreadful crimes, causing an enormous sacrifice of human life, are committed. It is of further importance to the exporter to be able to analyse his beer, and from the results to deduce the original gravity of the wort; for by Act 10th Victoria, cap. 5, a drawback is granted of five shillings per barrel of thirty-six gallons upon beer exported, of which the worts used before fermentation are of not less specific gravity than 1054, and not greater than 1081; and a drawback of seven shillings and sixpence upon beer exported, the worts of which, before fermentation, were not under 1081 specific gravity.

The constituents most necessary for the analyst to determine in this case are, the alcohol, water, saccharine, glutinous, and bitter extractive matter of the hop; but a complete investigation of these will sometimes be necessary for the purpose of detecting any foreign or destructive principle introduced as an adulterant. Much may be learned from an attentive examination of the beer previous to its being submitted to analysis. It should be perfectly clear; turbidness shows that either the acetic or vinous fermentation is going on. The smell and taste of the hops, and the quantity of carbonic acid, which may be judged of from the creaminess of the head—unless head matter had been employed—afford to the connoisseur a means of judging of the quality of the ale with tolerable certainty.

For excisable purposes, the following is the method recommended for the analysis of beers, so as to find the original density of the wort. An accurately graduated four ounce bottle is provided and filled with the beer to be examined, after which the contents, together with the rinsings, are transferred to a retort to which a condenser is affixed, and the measured bottle is used as a receiver. Distillation is then continued till somewhat more than half the quantity of liquid is drawn over, so as to insure the elimination of the whole of the spirit. The remainder of the measured bottle is then filled with distilled water, and the specific gravity of the mixture taken. If, instead of 1000, the weight should indicate 987, it shows that the weight of the diluted spirit is 13° less than water; this is *the spirit indication of the beer.*

By referring to the Excise tables drawn up for this purpose, the density of the worts producing it will be ascertained to be 59·4. The residue in the retort must then be washed with a small quantity of distilled water into the four ounce bottle, which is then filled with water, and the gravity found as before, and its excess over that of water added to the preceding number, plus 1000, and the sum will be the original gravity of the wort. Thus—

If the spirit gravity be................	59·4
And the extract do.	1030·0
Gravity of the worts,................	1089·4

The annexed table, constructed by Professors GRAHAM, HOFMANN, and REDWOOD, is that by which the Excise are guided in most cases of this description. These numbers in the body of the table indicate the strength of wort corresponding to the spirit indication in the margin.

Degrees of spirit indication	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	0·0	0·3	0·6	0·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·9	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	59·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9
15	70·5									

When a more elementary analysis is required, a portion of the beer is well agitated, so as to dissipate the carbonic acid, and then a certain weight is taken and introduced into a retort connected with a condenser and receiver, and the whole of the spiritous liquor drawn off, and tested by either of the alcoholometric instruments pointed out at page 136, *et sequitur;* the amount of spirit is thus found on reference to the tables of the strengths of alcoholic liquors of different gravities, at page 118, *et sequitur.* The residuary matter remaining in the retort, after the most part of the fluid has been distilled off as just stated, is to be mixed with as much distilled water as will make up the same bulk of liquid as was originally employed, and the specific gravity of this liquid is to be taken by an accurate hydrometer. By this means the quantity of alcohol and extractive matter in the beer is found. To determine the amount of sugar in the solid matter of the beer, a portion of the liquor is weighed and introduced into a flask or beaker, and boiled; if a coagulum should form, it is to be collected upon a dry tared filter, then washed, dried, and weighed. The liquor is next evaporated till it becomes pretty thick; strong spirit of wine, or pretty concentrated alcohol, is then added, causing a precipitate of the gum and mucilaginous matter, which is collected and washed with spirit till all the sugar is extracted; it is finally dried and weighed, and its quantity noted. By evaporating the alcoholic filtrate to remove the spirit, dissolving the residue in water, and boiling the liquid with a grape sugar test solution, made by dissolving—

100 grains of crystallized sulphate of copper,
200 grains of bitartrate of potassa,
800 grains of crystallized carbonate of soda,

in 8750 grains, or one pint of boiling distilled water, and filtering if necessary, a precipitate of suboxide of copper falls, which, when collected, dried, and weighed, affords an indirect but accurate method for ascertaining the amount of saccharine matter, since every three grains of the suboxide indicate one of grape sugar. Having thus ascertained the per centage of albumen—if any—as also of gum and sugar, then, by deducting their total from the quantity of fixed residue, the difference will be the per centage of lupulin, or extractive matter of the hop.

If the beverage was impregnated with any of the products before mentioned they will remain, and be detected as extract of hops. Although a good many of these cannot be recognised by any chemical agencies with which the chemist is acquainted, yet, for the most part, they may be known by their taste, or other physical characteristics. Some of the organic substances, the extract of which is employed to impart bitterness, so closely resemble the hop, that they cannot be distinguished from the latter by any physical tests; one of these is the extract of the picrotoxin.

M. J. L. LASSAIGNE, during his researches upon *picric acid,* has made a distinction between the bitter principle of the hop and this acid. He says that, some time back, the fraudulent use of this acid as a partial substitute for hops had been announced, and that the practice was carried on to a considerable extent in certain districts in France. With the view of finding a ready means for detecting this adulterant in beers, he undertook the investigation. He observes that the taste cannot distinguish between the bitterness of picric acid and the lupulin of the hop; but that, by having recourse to the following experiments, the presence or absence of the adulterant may be readily ascertained. The beer is to be agitated with a solution of subacetate of lead in excess; this throws down a precipitate, consisting of the bitter and most of the coloring matter of the hop, whilst picric acid, *if present,* is unaffected by this reagent, and therefore remains, communicating its peculiar taste to the liquid. Another test, LASSAIGNE remarks, is this, that common bone charcoal, purified by acids, will precipitate and retain the coloring matter of the beer; but that picric acid passes through this medium, communicating its natural tint to the filtrate. Upon these applications he bases the method of recognizing very minute traces of the acid when added to beer.

In his experiments, to prove the efficacy of the test, he operated upon equal portions of a well-made genuine beverage, to one part of which one-twelve or one-eighteen thousandth of the adulterant was added.

On pouring into these samples subacetate of lead in excess, or on shaking them with powdered animal charcoal, the pure beer is almost entirely decolorized, whilst the adulterated sample retains *its yellow citron color.* The most minute traces of the adulteration may be detected by evaporating the liquid, and, when reduced to a half or quarter of its bulk, then applying the tests.

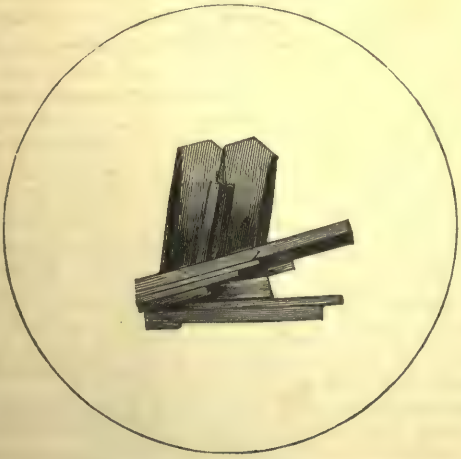
Mr. T. J. **Herapath** has lately published another test for the detection of the active principle of *cocculus indicus* in beers. It is based upon the property which charcoal possesses of separating picrotoxin from its aqueous solution. An excess of acetate of lead is added to the beer under examination, in order to throw down the humulin and other extractive matters; the precipitate is removed by filtration, and the excess of lead in the filtrate abstracted, by transmitting a current of sulphide of hydrogen gas through it, when it will fall down as sulphide of lead. To expel the free sulphide of hydrogen after the filtration of the precipitate, the solution is boiled for some time, then slowly evaporated, until the residue assumes a thick consistency, and a small quantity of pure animal charcoal is agitated with it for a few minutes.

When the whole cools the solution is filtered, and the charcoal, containing the picrotoxin, washed with the smallest possible quantity of water, then dried at 212° Fahr. After all the moisture is expelled, the charcoal is next boiled with some pure alcohol to dissolve the alkaloid accompanying it, the solution is filtered and evaporated, and the picrotoxin permitted to crystallize spontaneously.

If the adulterant be present in large quantities, it is deposited in fine well-formed prisms—Fig. 166—or when the solution is rapidly concentrated, and speedily cooled, the crystals have a beautiful foliated or plumose appearance, similar to Fig. 167.

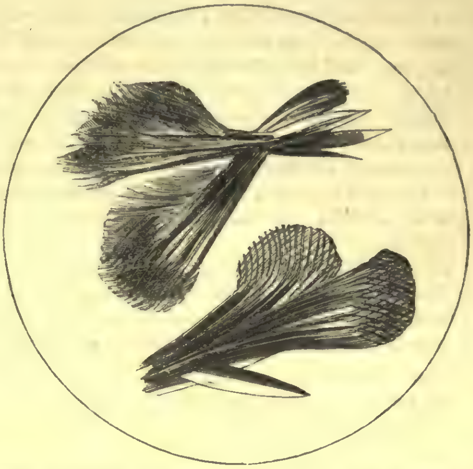
A small amount of this ingredient assumes the form of long radiating needles, which, if the crystallization be conducted as in general between two slips of glass, exhibit a peculiar tendency to place themselves nearly parallel with the edges of the upper glass. See Fig. 168.

Fig. 166.



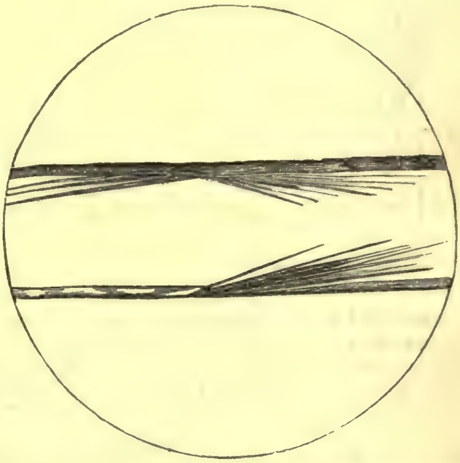
By this means it is said that the alkaloid can be detected in the beer, when only half an ounce of the extract has been added to the barrel.

Fig. 167.



The quantity of acetic and lactic acid in beer is determined by weighing or measuring a certain portion, and neutralizing it with a standard solution of pure carbonate of soda or of ammonia, added gradually from a burette, and calculating the per centage of those acids from the quantity of the test liquor employed. If lactic acid be suspected, another weighed portion of the liquid should be evaporated to dryness, the residue affused with water, and neutralized by the forementioned solution. From the number of measures required, the quantity of lactic acid is calculated. The equivalent of dry lactic acid is 90. By deducting the amount of lactic from the total weight of acid, as above ascertained, the remainder will be acetic acid.

Fig. 168.



Carbonic acid gas may be determined either by boiling a quantity, say a quart of the beer, and collecting the gas in a pneumatic apparatus, or, if this be not convenient, transmitting it into a solution of baryta or lime, and collecting, drying, and weighing the precipitate which it occasions. If lime-water be employed, every fifty parts of the precipitate will denote twenty-two of carbonic acid.

If inorganic adulterations be suspected, their presence may be proved by evaporating the beer to dryness, and incinerating the residue in a platinum capsule or basin, till the whole of the organic matter is dispelled, then dissolving the ash or fixed matter in hydrochloric acid, and testing—for iron, with sulphocyanide of potassium, which will give a blood-red coloration if it be present; for lime, by the addition of ammonia and oxalate of ammonia, which will cause a white precipitate. Should common salt be suspected, it may be proved by dissolving a portion of the residue, after incineration, in water, filtering, and adding nitric acid and nitrate of silver to the liquid; from the bulk of the precipitated chloride of silver, the presence or absence of salt is inferred. Some chlorides are naturally present, so that the formation of a slight opalescence does not prove the adulteration. Should alum be present, it will precipitate in the form of white flocculi, on adding ammonia to the solution when testing for lime.

Owing to its vast importance, the article Beer has been more fully discussed in all its relations, than at first sight it might warrant; but before appending the statistics of this extensive trade, it will, no doubt, prove interesting to the reader to know, that the largest ale establishments are those at Burton, the oldest of which, Messrs. **BASS, RADCLIFFE, and GRETTON**, brews the enormous quantity of 200,000 barrels per year; a very great proportion of this is bottled and sent to the East Indies. The next well-known house is that of Messrs. **ALLSOPP and SONS**; and the largest porter brewery in the world belongs to Messrs. **BARCLAY, PERKINS, and COMPANY**, of London. The three are well worthy of a visit.

STATISTICS OF THE BEER TRADE, SHOWING THE QUANTITIES OF HOPS AND MALT GROWN, MADE, EXPORTED, OR USED IN THE UNITED KINGDOM, AND THE BARRELS OF MALT LIQUOR BREWED UP TO CERTAIN DATES SPECIFIED IN THE TABLES.

Year ending 5th Jan.	British hops.											Foreign hops.								British and foreign hops remaining for home consumption.							Malt made in the United Kingdom. Oct. to Oct.
	Grown weight.				Old duty at 1d. and 15 per cent. per lb.			Exported weight.				Imported.				Exported.				Weight.				Duty at 1, 15d. per lb.			
	tons.	cwt	qr.	lbs.	L.	s.	d.	tons.	cwt.	qr.	lbs.	tons.	cwt.	qr.	lbs.	tons.	cwt.	qr.	lbs.	tons.	cwt.	qr.	lbs.	L.	s.	d.	quarters.
1841	3176	6	0	5	34092	6	2½	412	8	3	21	5	7	0	12	2	2	3	4	2767	1	1	20	29699	18	0	5,307,107
1842	13617	18	0	10	146165	10	1¾	171	7	3	9	1	14	1	8	6	6	0	17	13441	18	1	20	144276	12	5½	5,105,005
1843	15817	18	1	18	169779	0	3¼	295	18	0	16	—				—				15522	0	1	2	166602	18	10½	4,269,925
1844	12438	14	1	9	133508	17	9¾	130	13	1	25	1	7	2	14	1	0	3	22	12308	7	2	4	132109	18	2½	4,459,673
1845	13073	14	0	4	140324	7	11¾	68	13	2	17	13	7	0	19	1	18	2	12	13016	8	3	22	139709	17	4¼	4,617,247
1846	14720	17	1	17	158004	0	1¼	67	10	0	10	36	6	0	18	36	8	0	26	14653	5	0	27	157278	6	11	4,687,487
1847	22635	14	2	1	242956	15	8¾	200	4	1	21	164	3	1	24	28	17	3	8	22570	15	2	24	242259	15	4	4,987,350
1848	20149	5	1	17	216268	16	7¾	204	0	3	17	73	7	0	22	40	8	3	17	19978	2	3	5	214432	0	7¾	4,345,397
1849	19796	8	1	21	212481	11	10¾	159	7	3	1	19	5	0	23	10	9	1	8	19645	16	2	7	210865	4	5¼	4,913,004
1850	7433	8	3	15	79785	12	8¼	122	13	2	19	263	11	1	14	19	2	0	1	7555	4	2	9	81092	15	9¾	4,749,879
1851	21668	12	0	5	232576	6	7¼	120	15	1	3	324	0	3	22	97	12	0	26	21774	5	1	26	233710	10	10	5,183,617
1852	12072	14	2	15	129580	13	0¾	403	12	0	26	23	1	2	15	46	13	3	24	11645	10	2	8	124995	6	9¼	4,853,118
1853	22813	12	1	2	244866	2	4	426	14	1	9	15	9	0	14	7	15	2	6	22394	11	1	19	240368	6	11¼	5,088,758
1854	14174	17	1	1	152143	10	6¾	358	1	2	15	2115	15	0	27	84	15	0	7	15847	15	3	6	170099	12	3½	5,254,968

The total duty on hops is at the rate of twopence and five per cent. per pound, but the above amounts are calculated at the ratio of one penny and fifteen per cent. per pound weight—called the *old duty*.

The number of quarters of malt fabricated in the year 1841, refers to the quantity from the fifth of January, 1840, to the fifth of January, 1841, and the manufacture of 1854 denotes the total from the fifth of January, 1853, to the fifth of January, 1854.

	Quarters of malt made.		Quarters of malt used.					
			By brewers and victuallers.		By retail brewers.		Total.	
	1853.	1854.	1853.	1854.	1853.	1854.	1853.	1854.
England,	4,435,453	4,530,730	3,445,245	3,576,166	481,007	487,128	3,926,252	4,063,294
Scotland,	491,474	520,479	150,386	164,677	—	—	150,386	164,677
Ireland,	207,134	203,759	160,693	160,929	—	—	160,693	160,929
The United Kingdom,	5,134,061	5,254,968	3,756,324	3,901,772	481,007	487,128	4,237,331	4,388,900

From the above table it will easily be perceived that, from the fifth of January, 1853, to the corresponding date, 1854, the increase over the previous year in the quantity of malt made, was in

	Quarters.
England,	95,277
Scotland,	29,005

while in Ireland there was a decrease of 3,375 quarters, showing an increase for the United Kingdom of Great Britain and Ireland, of 120,907 quarters.

The increase in the quantity of malt used by brewers and victuallers in the same period was in

	Quarters.
England,	130,921
Scotland,	14,291
Ireland,	236
Increase in the United Kingdom,	145,448

The additional quantity of malt used by retail brewers in England is seen to be 6,121 quarters, and the total increase in the consumption of malt in the United Kingdom, 151,569 quarters.

The annexed table exhibits the number of barrels of beer brewed from 1815 to 1829, inclusive.

Years.	Barrels of beer brewed.	Years.	Barrels of beer brewed.
1815	8,169,368	1823	8,081,330
1816	7,985,961	1824	8,087,901
1817	7,131,255	1825	8,511,657
1818	7,221,191	1826	8,701,986
1819	7,549,337	1827	8,306,128
1820	7,184,889	1828	8,529,732
1821	7,471,033	1829	7,737,470
1822	7,683,850		

The duty on beer was repealed in the year 1830, since which date no account of the quantity brewed has been kept; but it is calculated that a quarter of malt, on an average, makes three and a half barrels of beer.

Years.	Bushels of malt used by brewers.	Years.	Bushels of malt used by brewers.
1830	20,790,058	1842	28,856,390
1831	28,717,257	1843	28,537,824
1832	28,417,501	1844	29,593,485
1833	29,566,125	1845	30,180,530
1834	32,139,650	1846	32,841,138
1835	32,830,220	1847	28,970,957
1836	34,235,822	1848	29,275,367
1837	32,186,882	1849	29,954,945
1838	32,323,485	1850	30,919,306
1839	32,073,882	1851	32,570,382
1840	31,887,427	1852	33,944,701
1841	29,408,511	1853	35,111,290

BENZOL.—*Benzine*, French; *Benzol*, German.—This compound, which has been described, from time to time, under the names benzene, benzine, phene, bicarbide of hydrogen, or benzol, is now a special object of manufacture and of commerce.

It may be procured to any extent from coal tar, or from the light naphtha; up to the present time little advantage, however, has been taken of it from either of these sources. Its application in the chemical arts is not extensive, but, from its many and varied properties, it seems calculated to fulfil an important mission; and these considerations induce the Editor to allot to it a separate article, rather than to class it amongst the other products obtained from tar by distillation.

FARADAY was the first to detect benzol as one of the substances emanating from the distillation of organic matter; MITSCHERLICH subsequently showed that it was the principal ingredient in the distillate obtained when hydrate of lime reacts upon benzoic acid at a high temperature. By either of these methods its produce, in any appreciable amount, to be useful in the arts, could not be expected; for, in the first instance, the method by which it was prepared was so imperfect that it could not be prosecuted on a large scale, and in the second, the fact that it was so obtained was more an acquisition to science than to the arts.

Among the many other investigations which have been recently made, that of Mr. MANSFIELD upon coal tar has developed the means whereby benzol can be economically obtained in the highest state of purity.

It is a clear, colorless, and very mobile liquid, having a characteristic agreeable ethereal odor. The boiling point, as stated by MITSCHERLICH, is 186° Fahr., but that prepared by MANSFIELD from the crude naphtha spirit, enters into ebullition at 176°, the ordinary pressure and temperature of the atmosphere being applied. At 32° it crystallizes in masses resembling white wax or camphor, like which it will burn without immediately entering into fusion. By a gradual refrigeration it is obtained in beautiful cruciform leaflets, perfectly transparent, which aggregate into forms resembling fern-fronds, with numerous pinnæ diverging at right angles to a principal axis. Its specific gravity in the liquid state is 0·85; that of its vapor, according to calculation, is 2·738, whilst experiments have shown it to be 2·770. It is insoluble in water, but alcohol and ether dissolve it; hydrated acids have no effect upon it, and the alkali metals, potassium and sodium, when immersed in it suffer no change.

Its composition has been shown by MITSCHERLICH, the Editor, and others, to be that of a hydrocarbon, with the formula $C_{12}H_6$; but the Editor, with many others, thinks it probable, from the facility with which it is converted into nitrobenzol—$(C_{12}H_5)\ NO_4$—by the replacement of one equivalent of hydrogen by peroxide of nitrogen—NO_4—that it is a hydride of the phenyl radical, namely, $(C_{12}H_5)\ H$.

In procuring benzol, the course adopted by MANSFIELD was to subject the light coal naphtha, which was drawn over at the beginning of the distillation of the tar, to repeated rectifications, and then to submit it to a cold of 32° Fahr. or under, when it crystallizes. As other compounds, having nearly the same boiling point as benzol, and allied to it in other respects, were suspected to be present, the solid matter was filtered under pressure, with the view of removing them if possible. In executing this part of the work, the operator employed a *Beart's coffee-pot*, as being well adapted for the purpose; and by repeated filtrations under the atmospheric pressure and a low temperature, he succeeded in obtaining a pure product, possessing the properties already enumerated.

As benzol has the same boiling point as alcohol of specific gravity ·825, the author of this research suggests that it may be obtained from the other products accompanying it in the crude light coal naphtha, by similar means to those which are resorted to in rectifying spirit. He recommends the adoption of a metallic retort, which should be surmounted by an open vessel filled with water, and containing a worm or chamber, into which the vapor of naphtha passes directly from the retort, and so arranged that the less volatile fluids, which may be condensed in it, will run back into the cucurbit, or into a separate receiver; while the fluids more volatile than water will flow on to another condenser, which is kept as cold as possible. The water surrounding the head of the still will gradually rise to the boiling point as the operation proceeds, and when this happens the distillation comes to a close, since no fluid remains in the retort, the vapor of which is not condensable at the temperature of the head, which, of course, cannot exceed 212° Fahr.

Rectification of the distillate having been effected a second time, in such an apparatus, limiting the temperature of the head to 176°, and reserving the portions which come over before the heat of the water rises to 194°, a large quantity of a very volatile liquid will be obtained, which, to at least one-half its bulk, will become solid when exposed to a cold of 4° Fahr. By carrying on the distillation as near as possible to the boiling point of the benzol, either by multiplying the condensers, or otherwise, the richer will be the crop of solid matter obtained from the distillate when subjected to cold. This product should be agitated with about a quarter of its bulk of sulphuric acid, or, better still, with about a tenth of strong nitric acid, and, after its removal, with one-fourth its volume of sulphuric. It should then be separated from the acid and distilled, or the distillation may be carried on from the acid, reserving in either case those portions only which pass off under 194°.

The distillate, after agitation with sulphuric acid, should remain perfectly colorless, and the acid should not assume a deeper tint than a straw-brown; if it acquires a darker hue, the product should be subjected to another rectification. When the proper purity has been attained, the volatile liquid should be well washed, first with water, and then with an alkaline lie, to get rid of all traces of acidity. The use of the sulphuric acid in this case, is to remove all the basic substances, to oxidize the small amount of brown coloring matter, and take away such of the neutral oils as form compounds with it. In the latter class, an oil of an alliaceous smell, more volatile even than benzol, is withdrawn by the acid. By treatment with nitric acid, the same volatile hydrocarbon yields a fragrant oil, the odor of which is not to be distinguished from that of oil of bitter almonds, so that this substance—at present used very extensively in confectionery and perfumery—may now be procured from coal-tar in tons, if required, and at a trifling cost.

The direct purposes which benzol may be made to serve are numerous: it is a very economical solvent for caoutchouc and gutta-percha; and from its great volatility, when the surface of bodies, such as glass or textile fabrics, is coated with the varnish, it deposits on it a very thin film. By these means, artificial cuticles may be formed on the body, which may be serviceable in case of wounds, burns, or cutaneous diseases. It dissolves many resins, mastic, camphor, wax, fatty and essential oils, with great facility. Some resins, such as copal, anime, *et cetera*, which are only slightly acted upon by the liquid, dissolve readily in the vapor at its point of condensation; hence its probable utility for varnish manufactures.

Sulphur, phosphorus, and iodine are taken up by it; the sulphur dissolves best in the boiling fluid, but it precipitates in a crystalline state as the menstruum cools. A current of air transmitted through this liquid becomes so surcharged with its vapor, that when ignited it affords a beautiful white light—in fact, it has been patented by a Londoner as a substitute for coal gas.

Ordinary coal gas passed over the surface of a bath of the fluid, acquires very great additional illuminating power.

Were it not that the price of alcohol is so exorbitant in this country, benzol would be the means of bringing it into use for some illuminating purposes, *et cetera;* for although alcohol and pyroxylic spirit do not afford much light when consumed alone, yet, by an admixture with benzol, they would be made to give a brilliant flame.

Similar mixtures of oil of turpentine and spirit are already in use in some localities in Germany; but benzol, as stated by MANSFIELD, is far more miscible with spirit containing a given amount of water than the oil.

It is an acknowledged fact, that the inhalation of its vapor causes, like chloroform, insensibility to pain, but from some slight irritation which it was found to produce when the experiments were made, it has not yet come into general use as an anæsthetic. Perhaps it may be questioned whether the benzol employed in these experiments was pure.

Benzol may now be considered of some importance, establishments for its fabrication being already at work in Manchester, Glasgow, and other large towns.

BISMUTH.—*Etain de Glace*, French; *Wismuth*, German; synthetically, *tin glass* and *marcasita.* This is one of the metallic bodies accounted *simple* by the modern chemists, though considered a *semi-metal* by the alchemists. Its discovery is of ancient date, being known to AGRICOLA, who wrote about 1530. Its leading features and properties were more fully studied by STAHL, CRONSTEDT, and KIRWAN; but POTT and GEOFFERY carried their investigations further than the others. Subsequently, BERZELIUS examined the metal and its combinations, so that at present its properties are well understood. Its dissemination in the mineral kingdom is not very extensive; in the native state it occurs at Scala, Neritia, Dalecarlia, Altenberg, Schneeberg, Annaberg, Johanngeorgenstadt, Joachimsthal, Baden, Wurtemberg, Hessia, Sweden, and Norway; it is also found in Cornwall and Cumberland in England, and at Stirling in Scotland.

The principal mineralogical combinations of bismuth, besides the native metal, are—bismuth ochre, bismuth blende, bismuth glance, bismutite, tellurii bismuth, bismuth silver, bismuth copper, and needle ore, the latter being a compound of bismuth, copper, and lead, with sulphur.

Of these, native bismuth is the most abundant, and is the body resorted to for the preparation of the element. In the laboratory, the metal is obtained by oxidizing the commercial bismuth with nitric acid, evaporating the solution, and adding a large quantity of water, which throws down a basic nitrate of bismuth. This precipitate is subsequently digested with potassa, to remove arsenious and arsenic acid, the solution filtered, and after the residue has been well washed, it is reduced at a gentle heat with black-flux.

Bismuth is very brittle, of a whitish lustre; but when compared with silver, zinc, tin, and antimony, its aspect is somewhat reddish; it cannot be drawn out under the hammer, but, by delicate treatment, a bar may be slightly extended. It crystallizes in cubes and tetrahedrons. These are best obtained by fusing a large quantity of bismuth in a crucible, and cooling it very slowly, till it assumes a semi-solid consistence; for this purpose the crucible, with the fused metal while red-hot, is embedded in hot sand, and covered over with an iron plate, heated to dull redness, and having some glowing coals placed upon it, to prevent the surface of the metal becoming too rapidly solidified; after a short time the lid is removed, a hole made in the solid crust of the content of the crucible, by holding a glowing coal or a red-hot bar of iron in close proximity, and then the liquid metal is poured out, leaving considerable portions adhering to the sides of the vessel. Upon examining this solid mass, it will be found beautifully crystallized in cubes and hollow tetrahedrons, as before mentioned. By exposure, the crystals instantaneously acquire a slight coating of oxide, which causes them to iridesce. It fuses at from 497° to 508° Fahr., and at a higher degree of heat it may be distilled from close vessels, and condensed in laminæ.

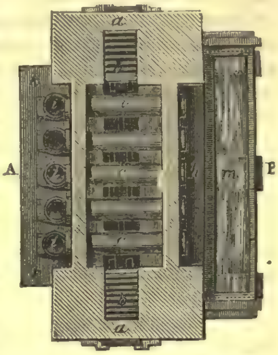
Regnault has stated that the vapor of bismuth is capable of decomposing steam, being oxidized thereby. Heated in the air, the metal burns with a bluish flame, and evolves light yellow fumes. Bismuth is not sensibly affected by exposure to a dry atmosphere; but in a humid, its feeble lustre is readily tarnished.

Pure bismuth has a density of 9·654, according to **Karsten**, though **Marchand** and **Scheerer** state it to be 9·799. The commercial article varies in density from 9·783 to 9·833; but this is considerably diminished by pressure. **Booth** says that the specific gravity of a bar of bismuth, on being introduced into a steel mortar, and a pressure of one thousand pounds applied, becomes reduced from 9·783 to 9·779; with the application of one hundred and fifty thousand pounds, the reduction comes to 9·655; and with a compression of two hundred thousand pounds, the density is lowered to 9·556. Bismuth has a very defective tenacity, a rod of one-tenth of an inch in diameter bearing only forty pounds; it is also wanting in sonorousness. It has been described as an electro-negative metal; but recent investigations upon its polarity, show that it is affected by electricity. Nitric and nitro-hydrochloric acids dissolve it with considerable energy; but if an electro-negative metal, such as platinum, be brought in contact with it during its solution in nitric acid, the action of the acid is arrested, and the bismuth becomes coated with a black film each time contact with the acid is broken; this blackness, however, readily disappears, and the metal assumes its usual brightness, being now only feebly attacked by solvents. A similar effect is observed if the metal be dipped in nitrous acid, and immediately afterwards into nitric acid. Bismuth decomposes water at a white heat, being converted into teroxide; it takes fire in chlorine gas, giving rise to terchloride of bismuth. It combines with most of the non-metallic elements, as also its oxide with mineral acids, producing corresponding salts, which, however, are not very interesting to manufacturers, though very much so to the scientific chemist. Bismuth is denoted by the symbol Bi; and the atomic or combining weight is 213.

It is for the most part a secondary product in metallurgical operations, as it is nearly always found, though in the native state, blended with more or less cobalt, silver, arsenic, *et cetera*. Eliquation, conducted with care, is all that is necessary to obtain the metal as sold in the market. The method of conducting this eliquation, the uses of the metal in the arts, and some of its more important combinations, will now be described. These will be found to consist in its alloys, oxides, and nitrates, the latter being chiefly employed for pharmaceutical purposes. A few remarks on the methods of detecting bismuth in combination will conclude the article.

Eliquation.—Cast-iron retorts placed obliquely, and heated by a furnace beneath them, are used for this purpose; and the bismuth of the ore with which these retorts are charged is fused, and flows along the inclination into an appropriate receiver, leaving siliceous and other impurities. The furnace constructed at Schneeberg is represented in the annexed Figs. 169, 170, 171; the first of which is a plan; the second a front elevation, at *k k*—Fig. 169—and the third a section, at A B—Fig. 169.

Fig. 169.



In the plan—Fig. 169—the fire-door is represented by *a*, the grate by *b*, and the eliquating pipes by *c c c*, which are made to incline towards the iron pans, *i i i*, where the fused metal is collected. A wall, *k k*, supports the pans; and to prevent the metal from forming an alloy with the latter, and also to obviate its oxidation, it is customary to throw a little charcoal powder into each. At *m* a tank of cold water is situated, into which the slag remaining in the pipes after the metal is separated from it is drawn. In doing this, the heated matter does not splash at once into the water, but falls along by a declivity, *h*. This arrangement is shown in elevation—Fig. 170—which is a section of the preceding, the same objects being distinguished by the foregoing letters. The pipes, *c c*, are closed at the depressed end by clay plates, denoted by *f* in the section, excepting a small opening through which the fused metal issues to the receivers, *c*; and a

Fig. 170.

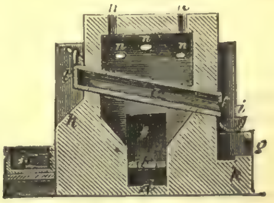
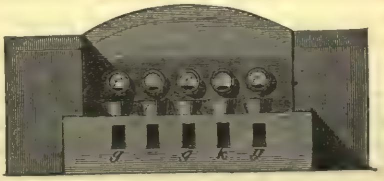


Fig. 171



stout cast-iron door-plate, *l*, secures them at the other. The retorts are heated by the fire, *e*, with the assistance of flues passing from it round each severally, as seen in Fig. 170, and Fig. 171, at *g g*. The draught of the furnace is increased at will by opening the holes, shown at *n n*, Fig. 170, placed between each pair of retorts.

The ore is prepared by breaking it up, and removing the very impure portions; this being effected, about half a hundredweight is introduced into each of the retorts, the door-plates, *l*, made secure, and the fire stirred up to communicate the required degree of heat. This charge should only be about three-eighths of the capacity of the retorts, in order that it may be conveniently stirred. After the application of the heat for ten minutes, the metal begins to flow out by the small space in the clay plate, *f*, at the end; and as soon as it is observed to slacken, the contents of the retort are stirred with a rake, a process repeated several times, till the whole of the metal is obtained, which is usually the case in half an hour. The slag, deprived of all the metal, is now raked out of the retorts into the water tank in front, and replaced by a fresh charge. As the pans, *i i i*, get nearly filled, the fused metal is ladled out and cast into bars, weighing each from twenty to fifty pounds.

At Schneeberg, where about ten thousand tons of bismuth are annually produced, wood is the fuel employed, fifty cubic feet of which is sufficient to work off a ton of ore.

As obtained in this way, the metal is generally impregnated with more or less iron, arsenic, sulphur, *et cetera*, which, however, may be removed by fusing with a suitable quantity of nitrate of potassa to oxidize these impurities.

Bismuth required for medicinal or other particular purposes, where purity is an indispensable quality, should be prepared as directed at the commencement.

ALLOYS.—The chief application of bismuth is in the formation of alloys; it readily unites with tin, lead, silver, mercury, and several other metals, producing compounds the density of which is over the mean of the constituents. Such is the characteristic of the alloy of lead and bismuth in equal proportions; it has a foliated texture, is brittle, and of the same color as bismuth. In bell-founding, bismuth is of great use; for, though wanting in sound, it communicates sonorousness in a high degree to the alloy it forms with tin. When these two metals are mixed in the proportion of twenty-four parts of tin to one of bismuth, the alloy is malleable; but it acquires brittleness according as the quantity of the latter is increased. An alloy of bismuth, tin, and lead, was designated *fusible metal* by Sir ISAAC NEWTON, on account of its low melting point, a name which is still retained.

A mixture of eight parts of bismuth, five of lead, and three of tin, melts at 202° Fahr., and, according to ROSÉ, an alloy composed of two parts of bismuth, one of lead, and one of tin, liquefies at 200·75° Fahr.

All these alloys are rendered still more fusible by a slight amalgamation with mercury, and are serviceable for taking casts of anatomical preparations. An alloy of one part of bismuth, two of tin, and one of lead, is employed as soft solder by pewterers; the same has been proposed as a bath for tempering steel instruments, and cake moulds, for the manufacture of toilet soaps.

Bismuth alloyed with other metals has been used to measure heat when applied to particular technical uses, as also to prevent the explosion of steam boilers; for the latter purpose it was first proposed by the French; but although such safety *rondelles* are ingenious, and seemingly calculated to answer the desired end, yet many boilers to which they have been attached have been known to burst before even the fusible bath liquefied. The reason for such sudden reaction is, that the expansive force of the steam developes itself so instantaneously, that the fusible metal could not possibly be affected by it. The composition of the *rondelles* varies according to the pressure of the steam required; they are so constituted as to enter into fusion, and give way to steam of a higher temperature, but considerably under that which would endanger the safety of the boiler.

OXIDES.—Bismuth unites with oxygen in several proportions, but that generally found is the teroxide. The suboxide of bismuth is merely interesting to the scientific chemist; it is, when obtained from the partial oxidation of the melted metal, or when the finely-divided metal is oxidized in the air, in the form of a reddish-brown substance; the same combination of bismuth and oxygen is obtained when the basic nitrate of the teroxide is digested with an excess of protochloride of tin, and the residue washed and dried *in vacuo;* in this state it is of a coal-black color. In the heat of the blowpipe flame, this oxide reacts like the suboxide of copper when treated with microcosmic salt—phosphate of soda and ammonia;—it does not unite with liquid acids, but in the heat it seems to combine with those which are fixed. The oxide of bismuth and its nitrate, and occasionally the subchloride, are the only compounds which are used in the arts. The former is prepared by dissolving the metal in nitric acid, and precipitating the solution by caustic potassa or soda; or by evaporating the solution of the ternitrate to dryness, and heating the dry mass to redness, by which the nitric acid is expelled, and teroxide of bismuth is obtained. This oxide is of a yellowish color, but by heat it is changed to a blackish glass, which assumes, on cooling, a yellow crystalline appearance. The evaporation of the solution of the ternitrate may be dispensed with, provided much water be added to it to throw down a basic nitrate of bismuth in the form of a white powder; by filtering this precipitate, washing with a little water, drying and heating to redness, the oxide is obtained, as in the preceding. A soluble ternitrate of bismuth remains in the liquid filtered from the precipitate already mentioned, as the annexed formula shows:—

$$\underbrace{4\,(\mathrm{Bi\,O_3\,3\,N\,O_5})}_{\text{Ternitrate of bismuth.}} + 6\,\mathrm{H\,O} = \underbrace{(\mathrm{Bi\,O_3\,3\,N\,O_5,\,2\,Bi\,O_3})}_{\text{Basic nitrate of bismuth.}} +$$

$$\underbrace{(\mathrm{Bi\,O_3\,3\,N\,O_5})}_{\text{Ternitrate of bismuth in solution.}} + \underbrace{6\,(\mathrm{H\,O,\,N\,O_5})}_{\text{Nitric acid.}}$$

The formula for this oxide is $\mathrm{Bi\,O_3}$; its specific gravity from 8·174 to 8·968; and it contains in a hundred parts, 89·87 of metal and 10·13 of oxygen.

It has been used to destroy the effect of colors which would be given by many substances that are used as fluxes, and also for fixing the gilding in the manufacture of porcelain.

TERNITRATE OF BISMUTH.—This is the only salt of bismuth which is manufactured to any extent; but even this is not prepared in large quantities, as its use is almost entirely confined to a few pharmaceutical applications. It is obtained by dissolving the metal in nitric acid, and evaporating the solution; if the nitric acid be strong, its action is so energetic as to cause the evolution of light vividly when brought into contact with the metal.

By concentrating the solution obtained in this way, the ternitrate of bismuth crystallizes in hexagonal, octagonal, and apparently in double oblique rhombic prisms, terminated by several planes; the crystals are transparent and colorless, soluble in dilute nitric acid, and decomposed by water, with the formation of a basic nitrate, which precipitates, and a neutral salt, together with free nitric acid, which remains in solution, as shown in the annexed formula. A temperature of 212° converts the salt into a neutral solid body, and a liquid which readily congeals upon cooling. When the heat is higher than 212°, some nitric acid and water pass off, and a basic salt remains; at a still higher temperature, the whole of the acid is eliminated, leaving the pure teroxide. By triturating ternitrate of bismuth with phosphorus, violent deflagration takes place; a similar phenomenon is produced, but in a feebler degree, by ignited charcoal.

The composition of the neutral ternitrate of bismuth is annexed, according to the under-named chemists:—

	Atomic weight.	Theory.	Berzelius.	Freundt.
1 Eq. of oxide of bismuth,	237	49·38	48·8	49·00
3 Eq. of nitric acid,	162	33·75	33·7	33·25
9 Eq. of water,	81	16·87	17·5	17·75
1 Eq. of ternitrate of bismuth,	480	100·00	100·0	100·00

Formula:—$Bi\,O_3\ 3\,N\,O_5 + 9\,H\,O$.

The chief use of the salt seems to be for the production of the basic nitrate.

BASIC NITRATE OF BISMUTH.—*Pearl white, pearl powder—magistery of bismuth; blanc d'Espagne*, French; *perlweiss, schminkweiss*, German. The mode of its preparation is very simple, requiring merely the addition of certain quantities of water to the neutral salt. The most economical quantity is about twenty-four parts of hot water to one of the neutral ternitrate, when forty-five per cent. of the subsalt is obtained. Too much water should not be used in washing the precipitate, as it is rendered more basic by this treatment; portions of it might also be redissolved, and the trouble of evaporating such dilute solutions, in order to obtain the soluble salt, would be expensive and inconvenient. The liquid filtered from the precipitate may be evaporated to dryness, or nearly so, and decomposed by a fresh addition of hot water, as in the preceding case; the first washings of the precipitate might either be added to it before evaporating, or used to decompose fresh quantities of the ternitrate, as also the acid liquor from the second decomposition, and in this way the whole of the bismuth is obtained as basic nitrate. It is better to evaporate the filtrate and first washings, for they contain too large a proportion of free nitric acid, which would in a great measure interfere with the precipitation of the subsalt of bismuth; but when this acidity is nearly removed by evaporation, then the subsequent filtrates, from the decomposition of the salt it contains, and likewise the washings of this precipitate, may be used with advantage.

If the bismuth contain any dangerous impurity, such as arsenic, it is absolutely necessary that such should be removed before the pearl white can be prepared from it. **DUFLOS** effects the separation by dissolving a hundred parts of the neutral salt in two to three hundred parts of warm water, then filtering the solution thus obtained from the insoluble arseniate of bismuth, and afterwards decomposing the filtrate with about twenty parts of warm water. Many chemists remove the arsenic by precipitating the solution of the nitrate with caustic potassa, and filtering the teroxide; the filtrate contains the arsenic as arsenite of potassa; the teroxide of bismuth is afterwards redissolved in nitric acid, and precipitated in the usual way.

This method is, however, much more expensive than the preceding.

Basic nitrate of bismuth obtained by the foregoing method is, after drying, a pearly white powder, of a loose texture, appearing, when viewed through the microscope, in crystalline scales. When prepared from acid solutions with little water, the crystals are more acicular, and of a silky lustre; the compound manifests an acid reaction with litmus paper.

The composition of basic nitrate of bismuth is very variable, a circumstance which has led to the supposition that there are several other definite compounds of this base with nitric acid: according to **PHILLIPS**, **GMELIN**, and **FREUNDT**, it consists—

		Centesimally of			
	At. weight.	Theory.	Phillips.	Gmelin.	Freundt.
1 Eq. of teroxide of bismuth,	237	81·44	81·64	80·67	80·60
1 Eq. of nitric acid,	54	18·56	18·36	16·41	14·95
Water,	—	—	—	2·92	4·45
1 Eq. of basic nitrate of bismuth,	291	100·00	100·00	100·00	100·00

Formula:—$Bi\,O_3,\ N\,O_5$.

The analysis of **GMELIN** closely corresponds with the formula—$Bi\ O_3\ N\ O_5,\ H\ O$, while that of **FREUNDT** agrees with $7\,Bi\,O_3,\ 5\,N\,O_5 + H\,O$. **PHILLIPS'** salt was procured from an acid solution.

Basic nitrate of bismuth has hitherto been advantageously used in medicine. It is administered principally in those affections of the stomach which are unaccompanied by any organic disease, but which apparently depend on some disordered condition of the nerves of this viscus; and hence the efficacy of the remedy is referred to its supposed action on these parts. It has been particularly prescribed to relieve gastrodynia and cramp of the stomach, to allay sickness and vomiting, and as a cure for pyrosis or waterbrash. Dr. **PEREIRA** gave it in the form of powder in conjunction with hydrocyanic acid mixture, and remarked that the patient seldom failed to obtain benefit from its use. Dr. **THEOPHILUS THOMSON** recommends it in doses of five grains, usually combined with three of gum-arabic and two of magnesia, given every four or six hours, in the diarrhœa accompanying phthisis. He thinks that, both for efficacy and safety, it surpasses our most approved remedies for that complaint. It has also been administered in intermittent fever and spasmodic asthma. **Hahnemann** directed a portion of it to be introduced into a hollow tooth to allay toothache. It was also used with advantage by Dr. **Pereira** in the form of ointment applied to the *septum nasi*, in ulceration of that part, and as a local remedy in chronic skin diseases.

In animals it acts as a local irritant and caustic poison, and appears to exercise a specific influence over the lungs and nervous system.

On the human frame it acts locally, in small doses, as an astringent, diminishing the secretion. It has also been denominated tonic and antispasmodic.

Large doses disorder the digestive organs, occasioning pain, vomiting, purging, *et cetera*, sometimes affecting the nervous system, producing giddiness, insensibility, and cramps of the extremities.

Subnitrate of bismuth is useful in increasing the fusibility of many fluxes without adding to their color. When pure it is employed in gilding porcelain, in the proportion of one part of the compound to fifteen of gold.

The best kind of pearl powder is used as a cosmetic, and communicates a pleasing brilliancy to the skin; for this purpose it is sold by the French druggists under the title of *blanc de fard;* it turns grey, however, by exposure, and sulphide of hydrogen gives it a dark-brown color. **Vogt** says, that when thus employed, it has produced a spasmodic trembling of the face, ending in paralysis.

Analysis.—To ascertain the quantity of bismuth, the process is not very difficult; but the results are not so exact as in other analyses.

If the compound under examination contains no other substance than bismuth, its oxide, or a salt of this oxide, there remains only to bring the body into the state of nitrate by acting upon it with nitric acid, heating the menstruum almost to ebullition, and then precipitating by means of carbonate of ammonia, which throws down the teroxide of bismuth. If the material submitted to analysis contained hydrochloric acid, then the carbonate of ammonia will not answer, and sulphide of hydrogen must be transmitted through the acid liquor till the whole of the bismuth is deposited as tersulphide; or, provided no other body be present, the same precipitate may be obtained by adding sulphide of ammonium to the liquid; the sulphide is then well washed, and removed while moist, with the filter, to a beaker glass, where it is converted into nitrate of bismuth by means of nitric acid. The decomposition of the sulphide of bismuth is effected as soon as the liberated sulphur acquires a yellow color, at which stage the liquor is diluted with water filtered from the paper, which is to be well washed, these washings added to the previous filtrate, and the accumulated solution precipitated by carbonate of ammonia, as before stated, taking the precaution of heating the liquid either before or after the addition of the precipitant.

If the metal be operated upon, its solution in nitric acid, precipitated in the manner here directed, affords the whole of the bismuth in the form of teroxide. The precipitate of teroxide, obtained in either of the above cases, is to be filtered and washed upon the filter with distilled water, then dried at 212°; and, when dry, it is to be detached from the filter as much as possible upon a sheet of glazed paper; the filter is next burned by itself on the lid of the crucible, and the ashes afterwards added to the precipitate, after it has been heated over a lamp in a porcelain crucible; the whole is then weighed. During the ignition the oxide changes to a yellow color; and if the heat be too high the mass enters into fusion, but does not, however, lose any of its weight by this behavior. From the weight of the teroxide of bismuth thus obtained, that of the metal is calculated; for every two hundred and thirty-seven parts of the former, contain two hundred and thirteen of the latter.

Bismuth being usually found in combination with other metals, and these being generally lead, silver, copper, arsenic, and iron, it may be interesting to give the process whereby the quantity of bismuth is ascertained when in combination with those substances; the method will also answer for the detection of any spuriousness in the preparations of bismuth, particularly when compounds of the enumerated metals are employed. The ore, or substance, is treated with nitric acid till dissolved, and this solution is filtered and diluted with water; the washings of the residue, if any, are added, and a stream of sulphide of hydrogen gas is passed through it as long as a precipitate is formed. The vessel is then gently heated upon the sand-bath till the whole of the sulphides fall down; these are filtered, and washed with water impregnated with sulphide of hydrogen; the substance upon the paper is next digested in a strong solution of sulphide of potassium, which dissolves the sulphide of arsenic, leaving the sulphides of lead, silver, copper, and bismuth intact, and which are separated from this solution by filtration and washing. These sulphides are then dissolved in nitric acid, the solution thus produced largely diluted, and the silver removed by hydrochloric acid. When the precipitated chloride of silver has subsided, it is filtered, and the filtrate and washings evaporated with an excess of sulphuric acid, till the latter begins to be evolved; sulphate of lead is thus formed, which is removed by filtering rapidly while hot, and washing the precipitate with very dilute sulphuric acid. The solution obtained from the sulphate of lead now contains copper and bismuth. To remove the bismuth, it may be treated with carbonate of soda in slight excess, which throws down the copper and bismuth as carbonates; cyanide of potassium is then added to decompose the carbonate of copper, a soluble cuprocyanide of this metal being formed. The residual carbonate of bismuth is collected upon a filter, washed well, and submitted to heat, after drying in the water-bath, as before directed; the result is oxide of bismuth, which affords the per centage of the metal by the foregoing calculation. The analysis does not, however, give the true quantity of bismuth; but, by careful manipulation, pretty accurate results are afforded. The quantity of each of the other constituents may be ascertained by weighing the precipitates already procured in case of lead and silver. By adding ammonia to the filtrate containing the iron, this body is thrown down as sesquioxide, which may be collected, dried, ignited, and weighed. Arsenic is determined by the method given in the article treating of this metal at page 221; and the copper in solution, after the precipitation of the bismuth, is ascertained by evaporating it with strong sulphuric acid, to decompose the cuprocyanide of potassium, after which the copper may be thrown down by the addition of caustic potassa in excess, and boiling the liquid; the potassa determines a blue precipitate of hydrated oxide of copper, which loses its water upon the application of a boiling temperature, and becomes black. By filtering this substance from the solution, washing well with boiling water, drying, subsequently heating to redness—apart from the filter—and weighing while still warm, with the crucible cover fixed on, the weight of oxide of copper is found.

The importation of bismuth is inconsiderable. It sells at about fourteen pounds per hundredweight.

BITUMEN–ASPHALT.—*Bitume*, French; *Erdpech*, German; *Asphaltum*, Latin.—Bitumen is a name used to denote various inflammable substances, of a strong smell and of different consistences, which are found in the earth. There are several varieties, most of which evidently pass into each other, proceeding from naphtha, the most fluid, to petroleum, a viscid fluid matter, more or less cohesive; elastic bitumen, or mineral caoutchouc, and asphalt, which is sometimes too hard to be scratched by the nail. It forms very extensive magazines in many parts of the world. It is sometimes found on the surface, exuding from the secondary or alluvial strata, where it is generally met with; but it is never found in the primary or older formation. The manner in which natural bitumen was formed is unknown, but it is supposed to be the result of the action of heat and moisture on the organic substances which have been buried in the earth at a bygone period. This heat, when exerted upon such matters out of contact with air, would, as is well known in the laboratory, effect a decomposition, the nature of which would be analogous to destructive distillation, but different, inasmuch as that the pressure exerted at the same time, would effect the liquefaction or solidification of many of the gaseous products evolved in the chemical process. There is still a question at issue, whether the bitumen has been derived from decomposed vegetal or animal matters? It would seem that the theories upholding these notions are often refuted by the nature and composition of the substance itself; generally, however, its vegetal origin is accepted as the most plausible. It would appear that a great deal of bitumen is formed from coal, or lignite, in the bowels of the earth, from the combustion of bodies, such as pyrites, *et cetera*. Sulphuric acid by the aid of heat decomposes organic bodies, giving rise to compounds, often bituminous, and similar to the natural product.

The largest bituminous deposits in the world are those of the Asphaltic Lake, or the Dead Sea, in Judea, and the Pitch or Tar Lake, in Trinidad. Besides these extensive formations, bitumen is found in many other parts of the world; namely, in France, at Hatten, Bechelbronn and Lobsann on the Lower Rhine; at Parc and Seyssel on the Rhone, in the department of Ain; in the departments of Auvergne, North, *et cetera*. Considerable quantities are found in South America, particularly at Coxitambo in Peru; in the islands of Cuba, Barbadoes, and in many parts of the West Indies; it is likewise found in Albania; near Naples, in Italy; in Persia, and in various other parts. In England, very little, comparatively speaking, has been met with. It is produced at the coal mines of Hurlet near Paisley, where it encloses crystals of calcareous spar, and at the Odin mines in Derbyshire. The peat cut on Downholland Moss, near Ormskirk, Lancashire, has been found strongly impregnated with it. Considerable quantities of bituminous limestone are found in East Lothian, in Scotland.

The bitumen is of three distinct kinds; namely, the earthy, the elastic, and the compact; the latter is termed asphalt. Earthy bitumens have a brownish-black, dull color, with an earthy, uneven fracture, and soft enough to take an impression of the nail; they burn with a clear, brisk flame, emitting a powerful odor, and depositing much soot. Elastic bitumen is of various shades of brown; it is soft, flexible, and elastic; it has an odor strongly bituminous, and is of about the density of water; it burns with a clear flame and much smoke; by a gentle heat it may be converted into a substance resembling petroleum or asphalt, according to its previous consistence. Like caoutchouc it takes up the tracings of pencils, and on this account it is called *mineral caoutchouc*.

Compact bitumen or asphalt is, as instanced above, extensively disseminated. It is of various degrees of quality, according to the quantity of impurities which accompanies it; but by simple operations the several species may be reduced to a state of equal purity, and the asphalt then possesses nearly the same properties from whatever bed or country it is obtained. Bitumen has a density less than water; but in consequence of the ingredients mixed with it, the gravity, when of the purest kind, is not less than 1·0 to 1·16, and frequently it is as high as 1·6. It has a black or brownish color, a resinous appearance, a conchoidal fracture, and when rubbed a slightly bituminous odor; it is opaque, brittle, and does not soil the fingers. The method generally adopted for purifying the natural asphalts is by boiling or macerating them with hot water, according to the freedom with which they part with the earthy and siliceous matters in suspension. During the action of the water, the sand and other ingredients fall to the bottom of the vessel, and the bitumen rises to the surface, or forms clots on the sides of the boiler, whence it is skimmed off, and thrown into a large cooler, where more water separates. To purify the bitumen thus obtained more completely, it is thrown into a conical-shaped caldron, and boiled for some time, during which the water and volatile matters accompanying it fly off, and the sand and other mineral substances fall to the bottom of the boiler, leaving the asphalt in the form of a thick fatty pitch, in which state it is sent to market, or applied to the various uses which it is made to serve. Such is the method followed at the Seyssel and Bechelbronn deposits, and in various other places. In the former of these, which is the most celebrated, there are three beds of bituminous matter; the first is sandy, the second calcareous and very fusible, and the third calcareous, but not easily fused. The Bechelbronn variety appears in the form of a bituminous sandy deposit, between two layers of clay; the working of the veins in both places is carried on by shafts and galleries. The bituminous schist lying near a stratum of lignite at Lobsann, when acted upon by boiling water, manifests a difference in its nature from those mentioned, as the bitumen from it does not enter into fusion like the others, but rises as scum to the surface, from which it is removed by skimmers in the usual way, and remelted at a higher temperature, for the purpose of driving off water and separating the sand, which is done by decanting the bitumen, after the impurities have subsided. The clayey and siliceous residue is used to manufacture gas, and the bitumen employed for common asphalting. At ordinary temperatures, the bitumens of Seyssel and Lobsann are tenacious, and in cold weather they become solid; the Payta deposits, those of Magdalena and Trinity island, yield similar bitumens. The Bechelbronn bitumen is viscous, and of a brown color. It is applied for many advantageous purposes, particularly as a substitute for grease to lessen the friction of machinery, and also for greasing the wheels of carriages. From being applicable to these and similar uses, it has been called mineral fat, Stein oil, Strasbourg grease, *et cetera.*

Little was known of these bodies previous to the researches of BOUSSINGAULT, EBELMEN, BERTIER, and others; but by the labors of these philosophers, especially the first two, their nature and composition are now pretty well understood. BOUSSINGAULT found that, on submitting the asphalts or bitumens of Seyssel and Bechelbronn to distillation, they yielded more or less of a pale yellow oily liquid, which he named *petrolene,* on account of its being always an essential ingredient of petroleum. When those bitumens were heated to 212°, nothing passed over, showing that they contain no naphtha; but on raising the heat to about 450° Fahr., the oil was disengaged. According to this chemist, this oil when pure is of a light yellow color, possesses a bituminous odor, but little taste; it boils at 536° Fahr., giving a vapor of the density 9·415; hence this liquid is isomeric with the essential oils of turpentine and lemon.

The specific gravity of petrolene at 69·8° Fahr. is 0·891. It burns with a very sooty flame, dissolves very sparingly in alcohol, but ether takes it up in greater abundance. Its composition may be represented by

	Atomic weight.	Theory.	Boussingault.
20 Eq. of carbon,	120	88·23	88
16 Eq. of hydrogen,	16	11·77	12
1 Eq. of petrolene,	136	100·00	100

By treating the petroleum—viscid bitumen—of Bechelbronn with alcohol, it assumes great consistency, and the spirit becomes charged with the petrolene; but it cannot be wholly removed by this menstruum even when submitted to distillation, for as the alcohol loses its fluidity by uniting with portions of the matter, it also loses its solvent action in proportion. The best way to proceed is to keep the matter at a temperature of about 482° Fahr., by means of an oil-bath, till it no longer loses weight. By this means the petrolene is entirely separated, and a solid body remains which is black, very brilliant, has a greater density than water, and breaks with a conchoidal fracture; it burns like resins in general, leaving a very abundant coke. As this body possesses all the characters of asphalt, and forms the essential part of that bitumen, the above-named author called it *asphaltene.* It gave, upon analysis, the annexed elements in the proportions appended:—

	Centesimally.
Carbon,	75·0
Hydrogen,	9·9
Oxygen,	15·1
	100·0

These numbers correspond with the formula, $C_{80}H_{64}O_6$. From this analysis it would seem that asphaltene is produced by the oxidation of petrolene, thus:—Four equivalents of petrolene, $C_{80}H_{64} + 6\,O = C_{80}H_{64}O_6$, or one equivalent of asphaltene.

The following table shows the composition of a few of the bitumens:—

	Centesimally represented.			
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.
Viscous bitumen of Bechelbronn,	88·0	12·0	—	—
Virgin bitumen of "	88·0	11·0	—	1·0
Liquid bitumen from Hatten, Lower Rhine,	88·0	11·6	—	0·4
Solid bitumen of Coxitambo, near Cuença, in Peru,	88·7	9·7	1·6	

Annexed is a table of the analysis of several asphalts:—

		Centesimally represented.					
		Bitumen of Bastennes.	Bitumen of Pont de Chateau, Auvergne.		Bitumen of Abruzzi.		Bitumen of Monastier, Haute Loire.
			Crude.	Pure.	Crude.	Pure.	
Oily matters,	Bitumen	20·0	—	—	—	—	7·0
Carbon,		3·7	76·13	77·5	77·64	81·8	3·5
Hydrogen,		—	9·41	9·6	7.86	8·4	—
Nitrogen,		—	12 66	12·4	1·02	1·0	—
Oxygen,		—		0·5	8·35	8·8	—
Water,		—	—	—	—	—	4·5
Gas and vapor,		—	—	—	—	—	4·0
Quartz sand and mica,		76·3	—	—	—	—	60·0
Clay,			—	—	—	— Ferrug.	21·0
Ashes,		—	1·80	—	5·13	—	—
		100·0	100·00	100·0	100·00	100·0	100·0

Bitumen of Bastennes much resembles the sandstone variety of Seyssel, but it is much richer; it is compact and homogeneous in appearance, and of a dull brown color. Although it is solid at ordinary temperatures, yet it softens in the hand, and, therefore, cannot be pulverized. Boiling water separates bituminous matter only in very small portions, but ether and spirit of turpentine freely remove the whole of the bitumen. Alcohol has little effect upon it in the cold, and only dissolves very small quantities at a boiling temperature. This bitumen is used in the proportion of eight or ten per cent. with the Seyssel asphalt in making mastic.

The bitumen of the Pont de Chateau is solid, but softens even in the hand, and melts completely at a moderately high heat. It has a conchoidal fracture, and a fine black color; its density is 1·068 at 53·6° Fahr. It almost completely dissolves in essence of turpentine, but only partially when treated with ether. If it be thrown upon the fire, it burns with a crackling noise, and scintillates, on account of the evolution of water; when, however, it is heated in a glass tube gradually, it intumesces, and parts with its water without any decrepitation.

Bitumen of Abruzzi is solid, very brittle, has a conchoidal fracture, and shines like jet. Ether scarcely attacks it, but it is largely dissolved in essence of turpentine. At 55·4° it has a density of 1·175; it begins to soften at 212°, and fuses completely at 284° Fahr. without losing water.

Three kinds of bituminous mineral have been of late years discovered at Monastier, in Haute Loire, which considerably differ from the preceding, inasmuch as they are not acted upon in the least by boiling water; they neither agglutinate nor soften when ignited, but burn with a vivid flame, leaving a dark-brown ash.

Ether and essence of turpentine readily attack these bitumens, but they do not completely dissolve them, yielding deep red-brown liquors; alcohol abstracts rather more bitumen from them than ether and essence of turpentine. When distilled, they evolve oils and much water.

Bitumen of Cuba is largely imported into Europe, and passes by the name, asphalt of Mexico, or Chapopota, but comes in reality from the environs of Havannah, in the island of Cuba, where it exists in abundance. **Dumas**, speaking of this bitumen, says it is solid, very brittle, conchoidal with a large fracture, and of a very fine black; but its powder takes a brown tint; it exhales a very strong though not unpleasant odor. Grains of quartz sand may be distinguished in it here and there, and also particles of wood and straw. Its density differs little from that of water; some pieces swim in that liquid, and others sink to the bottom. It softens at a moderately elevated temperature, and melts completely in boiling water into a thick liquor, which rises and floats upon the surface in the form of a scum or pellicle. Acids and alkalies leave it intact. Alcohol dissolves a small portion of it, and the solution afterwards becomes milky upon the addition of water. Ether and essence of turpentine abstract half its weight, leaving a granular black substance, fusible at a temperature above 212° Fahr.; the ethereal extracts have a deep red hue, and when they are evaporated, the bituminous matter remains of the same color, soft and transparent. When calcined in close vessels, it swells up and leaves about 0·10 per cent. of a brilliant and extremely light coke. The oils which separate from it are brown and viscous.

Considerable quantities of bitumen are imported from the Dead Sea, in Judea, on the shores of which it is thrown up and collected; hence its commercial name is Jewish bitumen. This variety has a density of 1·16; it resembles ordinary pitch in color and fracture. Boiling water melts it; and when distilled, it yields a peculiar bituminous oil, some water, and traces of ammonia. It leaves about one-third of its weight of charcoal, which, upon being burned, affords an ash composed of silica, alumina, oxide of iron, with traces of lime and manganese.

The Tar lake of Trinidad is about three miles in circumference, and of an unknown depth, and forms the largest bituminous deposit in the world. It is situated in the highest part of the island. The odor from it is perceptible for many miles. To a distant spectator it appears like a sheet of water undisturbed by the least ripple, on a nearer approach it looks as if it were glass. It has been found that this bitumen, which is quite solid at the surface, is soft when cut into, and interspersed with cells, which contain petroleum. In hot weather, the surface of the lake softens to the depth of an inch, and therefore cannot be walked upon at those seasons. Large fissures frequently occur, and from this circumstance the pitch is supposed to float upon a body of water. In the neighborhood of this lake, liquid bitumen is found in holes and fissures in the ground, to the depth of about two inches; the soil also presents indications of volcanic action. The bitumen from this lake does not easily burn, but a gentle heat renders it ductile; it does not seem to be much used for asphalting purposes, but when mixed with grease it answers well for paying the bottoms of ships, and is employed to protect them from *teredines*—small worms.

Applications.—Speaking of the applications of asphaltum, **Dumas** says:—Some years ago, asphalt produced an industrial fever without a parallel in manufacturing annals; at that period the product was extolled beyond measure, and uses were assigned for it in every branch of the arts and manufactures, even in cases where common sense alone might have been sufficient to demonstrate its inefficiency. A reaction, unfortunately too complete, soon did justice to this unreflecting preference; asphalt fell into undue discredit, but, nevertheless, it is slowly recovering its estimation, and certain it is, that its valuable qualities, turned to account with more discrimination and judgment, will render lasting services to many departments of industry. All are, however, acquainted with the use of asphalt in making floors, laying down pavements, and the like.

A more recent application consists in preparing conduits of the largest dimensions, by means of pretty thin tubes of plate iron or glass, covered externally with a coating of bituminous mastic, of from one to one and a half inch in thickness. These economical conduits, so easy to lay down, would seem calculated to yield results attended with considerable advantage. M. **Chameroi**, who devised and employed in Paris bituminized pipes of plate-iron, has hitherto discovered no essential defect in them. The pipes of bituminized glass, lately proposed by M. **Hutter**, and made in the glass-works of Rive-de-Sier, promise the best results. It appears, in short, that bituminous mastic may be applied to a variety of purposes, analogous to those which have just been indicated. The tar may serve directly, and without being transformed into bituminous mastic, for several rather important uses. It has already been employed for impregnating paving-flags of sandstone, bricks, and other building materials; it communicates to these different objects the qualities which belong to itself. It is sufficient for this use of it, to heat the tar to 150° C.—302° Fahr.—and to plunge in it the sandstone or other materials of loose texture for two or three hours.

In 1851, Earl DUNDONALD sealed a patent claiming to make pipes from Trinidad bitumen, and also for fabricating pillars, pedestals, bases, *et cetera*, from the same material. Combined with cloth, he proposes to make it useful as a covering for ships' bottoms—between the vessel and the metallic sheathing—and as a lining for coffins. Another, and not the least useful of his applications of this important substance, is the coating of electric telegraph wires, especially when they are laid underground.

Bricks of very bad quality become excellent for various purposes, after being thus saturated with tar. In fine, the tar may be further employed with much success as an article of fuel; and it has been applied for this purpose in several gas-works.

It has been ascertained by experiment, that two and a half hundredweight of tar may be used in heating the distilling retorts, as a substitute for rather more than four hundredweight of coke. Hence it is evident that tar might be employed with advantage.

No one can well gainsay that it is a very remarkable fact in the history of the useful arts, that asphalt, which was so generally employed as a solid and durable cement in the earliest constructions upon record, as in the walls of Babylon, should, for so many thousand years, have well nigh fallen into disuse among civilized nations.

France, the emporium, as it were, of bituminous deposits, has lately been most diligent in rendering this article subservient to her comfort, so much so, that her capital and large cities may be said to have become as museums of asphaltic appliances. Her mines of asphalt offer, on account of their quality, considerable advantages and inducements for her advancement in this department. For asphalting roads, streets, *et cetera*, the two great requisites are, first, a concrete or bituminous stone, where the mineral constituents are so blended and enveloped in the bitumen as to be unaffected by contact with air or moisture for any length of time, and also to be able to resist sudden changes of temperature without being injured thereby—this forms the basis of the asphalting; and, secondly, a mastic or bituminous cement, which may be occasionally used with the former to give it more fluidity, and which is in like manner proof against air, moisture, and sudden changes of temperature. Both these substances are at the manufacturers' disposal in France, and no wonder, therefore, that with such, and their own enterprise, they manufacture a good article.

The best concrete is reckoned to be that from Neufchatel; it is massive, of irregular fracture, of a liver-brown color, and is interspersed with a few minute spangles of calcareous spar; it is easily scratched by the nail, but is still very irrefrangible. When exposed to heat, it evolves a fragrant ambrosial smell, a property which distinguishes it from factitious bitumen. Its density is 2·114, or nearly equal to that of bricks. When treated with oil of turpentine, it affords eighty per cent. of a white pulverulent carbonate of lime and twenty of bitumen.—*Ure.*

The qualification enhancing bituminous concrete and mastic, is the intimate combination of the mineral and organic constituents that enter into their composition. No artificial preparation of this kind, whatever may be the pains bestowed upon it, can be so homogeneous or combined as the natural compounds, for no means are employed to produce those necessary qualifications, further than a comparatively feeble heat, whereas the natural substance must have been formed under the influence of a much higher temperature, and an enormous pressure; hence the intimate union of the two principal ingredients is more perfect. The concrete from Neufchatel may be rendered suitable for the various uses in the way of asphalting, by mixing a definite amount of the petroleum of Seyssel or Bechelbronn with it, the mixture being rendered homogeneous by fusing it in a sheet-iron caldron. Common tar is sometimes used for the purpose, but petroleum is much to be preferred. At Lobsann, the asphalt is purified, as before stated, by the action of boiling water, and is subsequently fused by itself, to disengage water and volatile impurities. After the process of purification, it is melted and incorporated with bituminous limestone, pulverized and dried. When the mixture is sufficiently consistent, it is brought to a table, on which sheets of paper are laid, and upon these a square frame, intended to receive the plates of mastic, is placed; the mastic is poured out, and spread by means of a heated iron roller. There is a division in the frame, by which two plates are obtained, making together a little more than a square yard. The plates are sprinkled with bituminous sand, and may then be piled up in stock, or packed in bales. They are used with the sheet of paper beneath them. When laying these plates, they are united by a hot iron, and can be removed and soldered afresh in a similar manner, if required.

URE gives the following as the mode of preparing and laying the beautiful mosaic asphalt which embellishes the Place de la Concorde in Paris:—The ground was made uniformly smooth, either in a horizontal plane, or with a gentle slope to carry off the water; the curb-stones were then laid round the margin by the mason, about four inches above the level. This hollow space was filled to the depth of three inches with concrete, containing about a sixth part of hydraulic lime, well pressed upon its bed. The surface was next smoothed with a thin coat of mortar. When the whole mass had become perfectly dry, the mosaic pattern was set out upon the surface, the moulds being formed of flat iron bars, rings, *et cetera*, about half an inch thick, into which the fluid mastic was poured by ladles from a caldron, and spread evenly over.

The mastic was made by roasting the asphalt in an oven about ten feet long and three broad, to bring it to a friable state; the bottom of the oven was sheet-lead, and was heated by a brisk fire beneath it. A volatile matter—petrolene—to the amount of the one-fortieth of the weight of the substance was driven off, and the residue, after roasting, became so friable as to be easily reduced to powder, and passed through a sieve, having meshes about one-fourth of a square inch. The bitumen destined to render the asphalt fusible and plastic was melted in small quantities at a time, in an iron caldron, and then the latter in powder was gradually stirred in, to the amount of twelve or thirteen times the weight of the former. When the mixture became fluid, nearly two gallons of very small gravel, previously heated apart, was stirred into it; and as soon as the whole began to simmer and acquire a thick sirupy consistence, it was fit for use. It was then taken in buckets and poured into the moulds.

Various other beautiful pieces of asphalt have been laid down in the public places in Paris, all of which give satisfaction, from their continued cleanliness and resistance to the air and general traffic. In London, its application to paving purposes has not been so successful as anticipated; but whether this defect might be traced to the asphalt not being adapted to such appliances, or to the imperfect manner of preparing and laying it, is a matter unsettled. It would seem, however, that the want of success, in most cases, is due to the latter circumstance, for it is known that many of them were laid in rainy weather, a time most unpropitious for this operation. Further, it would seem that the mastic, on many occasions, was not manufactured with due attention to its nature, and therefore this might contribute to cause the defects; but whatever may be the reason, one thing is certain, namely, that unless the bitumen is thoroughly boiled to expel water and volatile oils, with which it is always impregnated, it will not, when laid down, resist the extremes of heat and cold so well as might be wished, neither will it remain unaffected by wear and tear; for those liquid impurities expand and contract with the forementioned changes, and on this account the asphalt cracks. In preparing the natural asphalt, it is better to pulverize the rock by means of heavy iron rollers, than to disintegrate it by heat, as described in the foregoing paragraph; in both processes for sifting the dust, however, a sieve is employed of ten meshes to the inch.

The object of the trituration is to convert the asphalt into mastic. For this purpose, a certain quantity of vegetal bitumen is added, proportional to the quantity of asphaltic rock then transformed into asphalt powder. Thus, for those operations, in which the cement requires to be endued with considerable elasticity, the proportion of bitumen ought to be greater; the contrary will be the case for firm and hard substances; and this proportion will still be different when the mastic is employed as a natural mortar.

In certain cases, asphalt is used in the state of powder, and not in the form of mortar; but this mode of applying it presents disadvantages which it is necessary to avoid, in order to obtain the conditions required for its good applications.

ARTIFICIAL ASPHALT.—This is prepared by means of the tar produced at the gas-works. It is, above all, requisite to transform this liquid tar into a fatty pitch, and for that purpose the essential oils, which hold it in solution, must be drawn off; the boiling must be continued till a sample, when cooled, assumes a soft consistence. The evaporation of the tar may be very well performed in the open air; but if it be desired to avoid the odor exhaled by the essential oils, and to collect the latter, which have a certain commercial value, it is necessary to conduct the operation in close vessels. An apparatus, which gives very good results, consists in a cucurbit of sheet-iron, with a bottom made convex in the interior, placed immediately over a fire; the products of the combustion, after striking the bottom of the cucurbit, circulate round it, then proceed under a second boiler to heat the tar contained in it, and from which the cucurbit is replenished when requisite. This vessel, when three quarters full, contains nearly twenty-four hundredweight of tar; it should be perfectly embedded in masonry; the capital itself, by which the volatile products escape, ought to be covered with materials that are bad conductors of heat, such as ashes, *et cetera*. Without these precautions, the essential oils, which have a very small amount of latent heat, would condense, and fall back indefinitely into the evaporating boiler. To collect the oils, they are made to pass into a tube cooled by a current of water, proceeding in an opposite direction to that pursued by the vapors; they are then received in a close vessel. A tube, branching from the vessel, conducts the uncondensed products outside the building in which the distillation is performed. This precaution is necessary to avoid the risk of conflagration; for these condensable oils have always a certain tension, and, consequently, yield vapors tending to diffuse themselves in the atmosphere. When the tar is brought to that state in which it assumes a soft consistence on cooling, it is withdrawn through a large eduction-pipe, and received into a third hemispherical boiler of cast-iron. When the bituminous mastic is to be prepared directly from this fatty pitch, the latter is kept in a state of fusion by a supplementary fire placed under the cast-iron boiler, and chalk in sufficient quantity is then added. This chalk ought to be previously ground to a coarse powder, dried on plates of cast-metal, and then passed through a sieve of iron wire. By adding heated chalk to the pitch, the mixture is accomplished better and more rapidly. The mastic is more solid in proportion as a greater quantity of chalk is added; but, on the other hand, it becomes less binding and more brittle. To mould the bituminous mastic, and thus impart to it a convenient form, a long table is spread over with cast-iron plates. A frame surrounds the table, which is subdivided into eight or ten compartments, by means of rules of about six inches in height, introduced vertically into grooves formed at equal intervals in the long sides of the frame. The eight or ten moulds obtained by this arrangement are coated internally with a paste, composed of sixty parts of water and forty of chalk, and which has the effect of preventing the adherence of the mastic to the sides of the mould.

Two barrels of tar, of four and a half each, or nine hundredweight, lose by distillation one-fourth, which is composed of one hundredweight three quarters and fifteen pounds of essential oil, and one quarter and thirteen pounds of water; there remain, therefore, about six hundredweight three quarters of fatty pitch. The essential oils, procured by the distillation of the tar, have of late years received much attention from manufacturers on account of their utility in the preparation of varnishes, and for lubricating machinery, as illuminating media; and for the preparation of a superior lamp-black. Again, by blending it with coal-gas, it would render its illuminating power greater; for this purpose it would be sufficient to pass the gas over the surface of a shallow vessel covered with these oils. The naphtha prepared from tar, and consumed in the patent lamps of Halliday of Huddersfield, affords a most brilliant, and at the same time a cheap light.

The most advantageous use of natural or artificial mastic consists in applying it to the purpose of obviating the bad effects arising from moisture. It is excellent for protecting houses against damp; in this case it ought to be applied in thin layers to cover the whole surface of the ground. It may be used as a roofing; for cementing tanks, fountains, and cisterns, which it protects from any infiltration; as a substitute for pavement, macadam, and flags, in roads, courtyards, footwalks, *et cetera.* Terraces are rendered impermeable to moisture by means of a layer of asphalt, and in such cases it proves a highly economical substitute for sheet-lead.

Asphalt, as generally used in this country, is made from ordinary pitch, boiled down with a species of dark-brown bituminous limestone from the Jura mountains, previously ground and dried for the purpose. The limestone is, however, only employed in the manufacture of the better kinds, for chalk is often substituted, and some allege with results equally good. The proportions taken are regulated by the use to which the mastic is subsequently to be applied; and having mixed them they are boiled down to a thick sirup, after which the semifluid mastic is run into square or circular moulds to cool, when it forms blocks of about a hundred and forty pounds each.

Sometimes ground or fine sand enters into the asphalt in equal proportion with the chalk or limestone; but, in some instances, only half as much sand as of chalk is used. It is necessary during the fusion to keep the contents of the caldron well stirred, as well to prevent the tar adhering to its bottom, by which it would get burned, as also to bring the ingredients into intimate combination, and to give the mass a homogeneous composition. As soon as the whole is thoroughly mixed, the proper consistency acquired, and aqueous and oily vapors are found to be disengaged only in very minute quantities, the asphalt is run off into the moulds as before stated; and in this form it is purchased, or conveyed to the place where it is being laid down.

Claridge, who took out a patent for asphalting, directs that the blocks of mastic should be fused in a portable boiler, similar to Fig. 172, and a quantity of mineral tar added, in the proportion of one pound to every hundredweight of the mastic. The tar is fused in the boiler, the mastic then introduced to the amount of fifty-six pounds, and the whole repeatedly stirred to prevent depositions. As soon as the contents of the boiler have been properly melted, the caldron is covered over for a quarter of an hour, after which the remaining quantity of the mastic is added, and its fusion proceeded with as above, the process being repeated until the boiler is full, allowing an interval of from ten to fifteen minutes between each operation. When the mastic is sufficiently fluid, it will drop freely from the stirrer, and jets of light smoke are observed to issue from it. If stiff mastic be required, the proportion of tar is lessened, and a quantity of coarse grit or river sand, to the amount of twenty or thirty pounds to the hundredweight, added. In laying the asphalt, the greatest attention and care must be devoted to the preparation of a solid and dry foundation. This is usually accomplished by removing or ramming the loose earth, and placing upon the bed a layer of coarse sand mixed with powdered limestone, in the proportion of seven parts of the former to one of the latter, and the whole pressed or beaten solid; upon this a second layer of finer materials is laid, compacted, and levelled; the bed thus prepared is allowed to dry before coating it with the mastic.

Fig. 172.

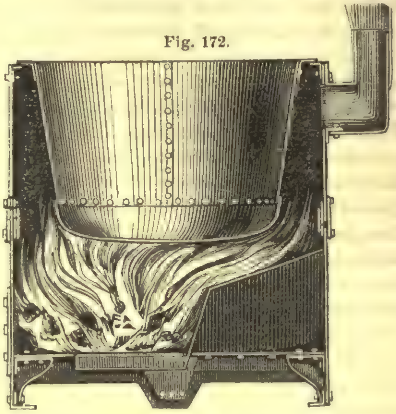
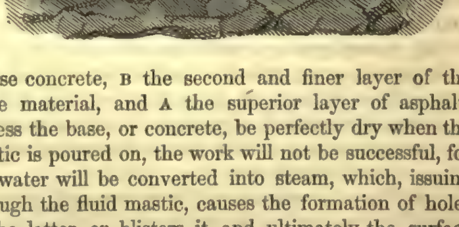


Fig. 173 shows the manner in which ordinary asphalting is laid down. In this figure, c is the bed of coarse concrete, b the second and finer layer of the same material, and a the superior layer of asphalt. Unless the base, or concrete, be perfectly dry when the mastic is poured on, the work will not be successful, for the water will be converted into steam, which, issuing through the fluid mastic, causes the formation of holes in the latter, or blisters it, and ultimately the surface would crack. For this reason, winter is the worst season for laying down asphalt, except in some place under

Fig. 173



cover. To counteract, in some measure, the evil arising from the formation of steam, it is found advantageous to sift fine cinder dust over the bed of concrete previous to the laying on of the liquid mastic. The depth of the layer of mastic is regulated by slips of wood, so arranged as to divide the surface into compartments of convenient size, and when laying the asphalt these compartments are filled up alternately; in this way there is no fear of one part being injured or defaced by the workman, as the alternate layers will be quite stiff when the intermediate spaces are being done. A curved wooden spatula, to which a straight rule of the breadth of the compartment of asphalt, and the ends of which move upon the slips of wood embedded in the concrete, is affixed, is rolled back and forth immediately after laying on the mastic, to bring it to the proper level. When the surface is to be retained smooth, a mixture of equal parts of fine sand and slate dust, or two parts of sand and one of hydrated gypsum, or powdered chalk, is sifted over it before it is completely set, and rubbed in with a flat heavy wooden tool. When it is for a pavement, then fine river gravel, or coarse grit, is scattered thinly over and beaten into it. When asphalting suspension bridges, a sheet of canvas is generally spread over the concrete; in damp places, such as cellars and foundations, there is always a brick invert laid in asphalt beneath the concrete. The manner of doing this is by placing the bricks in rows at the proper depth and slope, and pouring a coating of asphalt about a quarter of an inch thick upon them. Before the mastic solidifies, the bricks are separated a little by passing a knife between them, thus affording the mastic an opening by which to seal up more thoroughly the connection. The concrete is afterwards laid upon this bed, and the layer of mastic upon this in the usual way. The thickness of the layer of mastic varies according to the attrition to which it is to be subjected; but the usual depth is from a quarter to one and a quarter inch. One great source of the non-durability of asphalting is, in the Editor's opinion, the very large quantity of sand which is used, as well in its preparation, as when laying it down.

In France, where the natural asphalt is found in abundance, the following are the operations pursued in laying it. The general preliminary is to dress the ground, and beat it down well so as to render it solid; it is then covered with a layer of pitch, four inches thick, and this is again covered with a thin layer of mortar mixed with fine sand.

The pitch must next be left to harden for some days, to avoid the bubbles and swellings which appear on its surface, after which the asphalt is spread upon it to the thickness of half an inch or more.

The ingredients are applied in the following proportion per square metre—10¾ square feet:—

FOR HALF AN INCH.

Mastic, ...	44 pounds.
Gravel, ...	26½ do.

FOR THREE-FIFTHS OF AN INCH.

Mastic, ...	53 pounds.
Gravel, ...	30·8 do.

It has been acknowledged that the flooring of stables is of great importance to the health of the horses; this has caused a particular flagging to be sought after, which consists in spreading an asphaltic pitch of four-fifths of an inch in thickness on the ground, previously well dressed and beaten; then, by means of an iron roller, which is drawn along the band or belt of bitumen, a paving in relief is obtained, which is found to be very advantageous, and resembles that done in the ordinary manner.

It is generally in works connected with lines of railway that the use of bitumen is appreciated. Thus, the copings of arches, of tunnels, and bridges, covered with a coating of pure bituminous mastic, unmixed with gravel, affords a complete protection against the infiltration of rain-water; but as the earth-covering above might contain stones, which would penetrate into the bed of cement, a coating of clay is spread over the asphalt to the depth of one or two inches.

For constructing terraces, the following arrangements must be made:—

If the ground of the terrace is of masonry, the surface must be well put together, and the joinings carefully closed; it is then covered with a layer of asphalt half an inch thick, mixed with half its weight of fine gravel.

When the building, on which the terrace is required, is of timber, the flooring must be formed with planks at least four-fifths of an inch in thickness, arranged very close to one another, and firmly nailed to the supporting beams or joists.

This flooring is spread with a layer of pitch an inch or two in thickness, mixed with a little chopped hay or moss, to increase the elasticity of the ground.

The pitch having time to be well solidified, is then covered with the asphalt in the same manner, and under the same conditions, as for terraces constructed on masonry.

The surface of the layer of asphalt ought to be grained over with fine sand, firmly compressed and beaten down, to intercept as much as possible the rays of the sun.

The application of two layers would afford still further security.

QUANTITY OF INGREDIENTS EMPLOYED PER 10¾ SQUARE FEET

Asphalt, ...	55 pounds.
Gravel,............................	28·7 do.

By having the flooring of granaries asphalted, the different kinds of grain are secured for a long series of years from the damage to which they are liable when kept in the ordinary stores, and which has the effect of abstracting yearly so large a proportion from the wants of the population.

In the lining of cisterns and reservoirs, the danger to be chiefly apprehended is the infiltration and absorption of the waters which they contain. Asphalt being alone calculated to obviate these disadvantages, its mode of application is exactly the same as when applied to the construction of store-pits.

In the same manner as for basins and cisterns, asphalt may be employed as *natural cement* in the construction of tunnels, to guard against the infiltration of water, and thereby avoid great inconveniences.

The principal points to be attended to in the construction of tunnels, are the same as when this kind of work is performed in the ordinary manner; only the stones must be perfectly dry, and brushed clean, if required, to facilitate the adherence of the asphalt, which ought to be from one-sixth to one-fourth of an inch in thickness between two consecutive stones.

M. A. **BABONEAU**, manager of the Val-de-Travers Company, has, within the last few years, taken out a patent for a system of portable boiler, or melting vessel, provided with an agitator, designed to perform on the spot the fusion and trituration of the asphalt with the bitumen, and then the mixture of the gravel with the mastic thus formed.

This improvement will still further promote the application of asphalt to useful purposes; it is no longer necessary, in fact, to prepare in the manufactory the blocks of asphalt and bitumen, an operation which required a special apparatus. The substances, as found in nature, are now transported in sacks to the place where they are to be used; the melting, trituration, and mixing, are performed on the spot at the moment when the substance is to be laid down. Moreover, the melting vessel is so ingeniously constructed, that it collects the gases, and absorbs all the disagreeable odor, to the advantage of the public health.

NAPHTHA—PETROLEUM, ROCK OIL, BARBADOES TAR, MINERAL TAR.—Bitumen is the term applied to the liquid bituminous substance, which in many parts is found upon the surface, and also at various depths in the earth. There are several kinds, named from some peculiarity either in their physical appearance, or the places whence they are obtained. There are three classes of this substance, namely, the fluid, the viscous, and consistent. The fluid and colorless kinds are called naphthas, from the oriental word *nafata*, signifying to exude or pour out, as this curious liquid does, into the water of pits worked on the shores of the Caspian Sea. Viscid petroleum seems to be liquid bitumen, the solvent being naphtha, or an analogous carbide of hydrogen; and the consistent varieties are known by the names of mineral pitch, or maltha, earthy petroleum, mineral tar, *et cetera*. Petroleum chiefly flows from beds associated with coal strata; common salt seems also to take a part in its formation, being almost invariably found in those localities which produce it in abundance.

The Birman empire furnishes the largest quantity of crude naphtha, which constitutes a valuable part of its industrial resources, as an article of export trade; and it administers besides to the domestic comfort of the people, as a source of fuel and illumination. A sandy loam, deposited upon alternate layers of siliceous and argillaceous matter, resting upon a bed of coal, are the geological characteristics of the district. The clayey bed in contact with the strata of coal, which is of a bluish color, contains the volatile fluid; and by sinking a shaft to some depth in this strata, the fluid, or rock oil, as it is termed, flows into it free from the least admixture with water. No less than five hundred and twenty wells that yield this liquid are in operation in the neighborhood of Yananghoung, on the river Irawaddi, and produce annually about four hundred thousand hogsheads of it.

A similar product is obtained from the district of Baku, near the Caspian Sea, a locality famed for its inextinguishable fires, which have continued burning for ages. They are occasioned by the ignition of the inflammable vapor exhaled from the soil, which is surcharged with the naphtha, and from the ignorance and superstition of the people are regarded with a degree of reverence. In both these places, and also in many others in which petroleum occurs, the inhabitants use it in lamps; and when a few clods of earth are saturated with the liquid and ignited, a fire is made by which they conduct culinary and other operations.

Fluid petroleum is found in many parts of Italy, in France, Switzerland, Bavaria, Sicily, Zante, Gallicia, Trinidad, Barbadoes, Scotland, and in some parts of England. The bitumen of the Dead Sea, and that of the Tar Lake of Trinidad, as well as the viscid varieties of this island, and of many other parts, such as those of Bechelbronn in France, *et cetera*, are apparently produced from the oxidation of liquid petroleum; and their composition, as exhibited in the formulæ annexed,

Naphtha or Petroleum,...... $C_{20} H_{16}$, or $C_{40} H_{32}$
Asphalt or Bitumen,........ $C_{40} H_{32} O_6$,

manifests this derivation in a striking manner.

Naphtha, or fluid petroleum, according to the opinion of many chemists, is formed by the action of heat upon bituminous matters, but others maintain that it is generated by the action of water. Large quantities of naphtha are obtained from the distillation of coal, and in the manufacture of pyroligneous acid.

The colorless naphtha from Persia is a light volatile fluid, known in commerce under the name of rock oil. Its specific gravity is about 0·853, while the analogous liquid from other places, and especially from the vicinity of the Caspian Sea, is only 0·836. It boils at 305° Fahr., and affords, upon distillation, a light volatile oil, whose density is 0·728, and boiling point 176°. The vapor of rock oil, when mixed with oxygen, explodes violently, giving rise to water and carbonic acid. It does not combine with water, but imparts a peculiar smell and taste to it. With strong alcohol, ether, and essential oils, it unites in all proportions. It dissolves sulphur, phosphorus, iodine, camphor, most of the resins, wax, and fats, as also caoutchouc, which it converts into a varnish. Ordinary pitch gives, upon distillation, a light liquid like natural naphtha; but, according to **MANSFIELD**, they are not identical, for the former, as has been shown by this chemist, **HOFMANN**, and others, is a compound of many volatile liquids, such as benzol, toluol, alliol, camphol, mortuol, nitrobenzol, *et cetera*, which are not found in the latter. Upon this difference of composition, the theory of the formation of rock oil, by water acting upon organic bodies, is based; and the fact that it has been found, in most cases, floating upon water, favors the supposition.

Naphtha, or petroleum, has been applied to several important uses in the arts; besides its value for illumination, for which it is employed very extensively in those countries where it is produced, it is of great assistance in the preparation of varnishes, as a solvent for caoutchouc. It has lately been prescribed, with some success, in many cutaneous affections, and it is supposed to be a valuable specific in other diseases. When incorporated with soap, it is productive of happy results, in depriving that detergent of its causticity, which reacts with great irritation upon delicate skins. If it were used alone, or with any of its solvents, it would act more as a rubefacient and irritant than as a soothing, cleansing, and purifying agent; but when united with soap, applied to the skin in the usual way, after it has cleared out the cutaneous pores, a film of petroleum is deposited, which proves a perfect remedy against the prickly heat of tropical regions, and is also efficient in preventing and allaying the eruptions which break out in temperate climates. Among the continental physicians, it was at one time supposed to be a powerful remedy against cholera, but of late nothing has been heard of this desirable property.

It would, perhaps, be well if medical men would experiment upon this subject, especially as this dreadful scourge appears to be daily becoming more prevalent in all parts of the globe.

BLEACHING—*Blanchiment*, French; *bleichen*, German.—Under this head will be considered, especially, the means resorted to for the purification of textile fabrics made of certain organic fibres, from colored and other impurities, which, whether they are naturally associated with the tissues, or added to serve some other purpose, communicate more or less color to the cloth, and, therefore, destroy the beauty of their whiteness.

In the process of calico-printing, with which bleaching is in a great measure connected, success cannot be attained without having such natural or accidental coloring matters removed; and the change involved in the performance of this operation, whether in cloths, fibres, or other organic substances, is termed *bleaching*.

Although the decolorizing of cloth goods constitutes the largest branch of the bleacher's art, there are other compounds, of some importance in point of industry, which likewise require depuration from certain colors before they can be advantageously introduced as articles of good commercial value; and hence due reference will be made to these, as opportunity serves, in the succeeding treatise.

Before entering minutely upon the subject, it is right to inform the reader that, in almost every instance where bleaching has been effected, it is executed by means of true chemical agency; and although much attention has been devoted to the subject, yet only very vague and unsatisfactory explanations of the actual interchange between the elements of the color and the bleaching body can be adduced. The chemist has been far more fortunate in the discovery of agents which bleach well and expeditiously, than he has been in attaining to the theoretical or real solution of the problem relating to the manner in which the change is effected.

The greatest triumph in this particular was the introduction of *chlorine* into the art, whereby the work of a crowd of operatives for whole months on the old scale of procedure, is now executed, with the assistance of a few hands, in a single day, or rather in a few hours, and consequently at a centesimal fraction of the expense.

This element was first discovered by SCHEELE in 1774; he termed it *dephlogisticated marine air*, and thought it a compound of the phlogiston—a hypothetical body, supposed to be combined with all matter, especially oxidized substances—united with the marine or hydrochloric acid of the present day. Succeeding investigators, however, showed that such was not the case, but that it was a simple indivisible body, and, on account of its peculiarity of color, DAVY called it chlorine. Notwithstanding that a great many of its leading properties were known for a considerable period, yet there was no application of these to effect any purpose in the art of bleaching, until the researches of BERTHOLLET led the way, by successfully employing it in the form of alkaline chlorides. At the time of the application of these salts, very many difficulties attended their use, and consequently great opposition was raised against them by several bleachers; but the fault lay in the imperfect knowledge of the chemical agency of those and other bodies employed to whiten the cloth. Some, whose faith in the efficacy of the new bleaching agents was more securely established by their greater skill and more extensive information, adhered to their use, and although, through inadvertence or the want of that foresight required to guard against failures in such operations, they often experienced great losses at the beginning, yet, taking the causes into consideration, and making fresh exertions in the endeavor to perfect the art, they were led, step by step, over every obstacle and difficulty to the present advanced state of the business, in which cloths or other materials are decolorized by processes at once certain and easily performed.

Bleaching is of very great antiquity, but where it originated is unknown. It may be reasonably supposed that, as soon as human knowledge extended to the manufacturing of clothing, the observation would be made, that the natural or original shade of color in such fabric was destroyed by its exposure to the atmosphere and rain, and also by occasional washing; hence the idea of bleaching, by constant exposure to light and moisture for a certain period, may have occurred. The oldest records mention bleaching, but do not state the precise methods followed; those accounts which specify any particulars of the operation, give them as being performed by alternate boiling, washing, and exposure to the air. In later periods, sulphurous acid was introduced, and still continues to be employed in many cases; but although this proved very efficient, the necessity of having large grass plots or fields at command, and the great amount of labor and long period of time which the process required, prevented anything like cheapness. The money paid for bleaching—so enormous was the amount of labor, and the expense arising from land rent, *et cetera*, together with the losses occasioned by unfavorable weather—would go very far at the present day to cover the cost of preparing the cloth from the raw fibre. And if these disadvantages, and also the long period which elapsed before the cloth became properly white, be taken into consideration, in comparison with the ease and speed with which the operation is now performed, it will readily be seen that the bleaching process has kept pace with the onward progress of the age. As many may be unacquainted with the manner of bleaching previous to the use of chlorine, a cursory notice of it, as well as a short historical sketch of the improvements introduced from time to time, may not be uninteresting in this place.

The first operation was the steeping, which consisted in immersing the yarn or cloth in a cold alkaline lie, or in hot water; when the latter was used, the steeping lasted for three or four days, but if the menstruum was alkaline, forty-eight hours sufficed.

The goods after this steeping were washed and boiled for four or five hours, again washed, and exposed on the grass for two or three weeks. After this period they were again boiled—or, as it was termed, *bucked*—washed, and again exposed on the grass, or *crofted*, as before. The alternate operations of bucking, washing, and crofting, were repeated five times, reducing the strength of the alkaline lie at each successive washing.

Having performed these, the next course was the souring, which, till about the middle of the last century, consisted in keeping the goods steeped during several weeks in sour milk. A writer at this period, Dr. Hope, suggested the use of dilute sulphuric acid instead of the milk, and by this improvement the time of souring was shortened to about ten or twelve hours. The bleaching was not, however, finished with this operation; the boiling, washing, souring, and crofting, had to be renewed and continued till the cloth appeared perfectly clear, and quite colorless. The period of boiling, *et cetera*, varied according to the quality of the goods; linens were seldom finished in less than six months, and cottons required from six weeks to three months.—*Napier.*

It would be almost a waste of time to examine the various explanations which were submitted concerning the changes effected during the preceding course of operations, inasmuch as they were all hypothetical, so far as the exposure to the air was concerned, in consequence of the composition of the atmosphere, of water, and of the coloring matter not being known. Many chemists of considerable note, attempting an elucidation of this question, fell into error, from which even Berthollet, in his researches upon the subject, did not escape. Such inaccuracies may be very readily pardoned when the imperfect state of chemical science at the time is taken into account. More modern writers describe the action which takes place during croft-bleaching as follows:—

Firstly, That the coloring matter unites with the oxygen of the air, and forms a soluble compound, which can be dissolved out by water or alkaline liquors on boiling; or the oxygen may enter into combination with the carbon or hydrogen of the coloring matter—in the first instance, yielding carbonic acid, which escapes, and in the second, forming water; leaving the remaining portion of the substance either colorless, or so constituted that it is soluble in water.

Secondly, That oxygen combines directly with the coloring matter, forming a permanent colorless substance.

Thirdly, That the bleaching is not so much due to the effects of the atmosphere as to water, for that one of the elements of this fluid combines with the coloring matter, producing the reactions alluded to in the first explanation.

Hence, in consequence of the purity of dew, it is better fitted for bleaching, and therefore, in those seasons of the year in which there is a heavier fall of mist, the bleaching will be accelerated. Such are the explanations given.

It is an admitted fact, that the sun's light is composed of luminous and chemical particles, the latter of which have great influence upon various compounds; and bearing in mind the fact that light favors bleaching, the conclusion that the colored body of the cloth is decomposed, is easily arrived at.

Mention has been made of the introduction of chlorine into the art of bleaching by Berthollet, and also of the opposition which it had to contend with. Its reception in England, from the recommendations of Watt and Henry, was not more flattering than on the Continent; it destroyed the cloth, did not give a permanent white, killed the workmen, and hence it required considerable spirit to continue its use. The first method of using chlorine in bleaching was to transmit it through water till the latter was saturated; into this solution the goods were put, and heat was then applied to bring the chlorine to act upon the coloring matter. Great inconveniences attended this method of bleaching, and, as an improvement upon the system, the solution was diluted, and it was found to effect the decoloration equally as well as the strong liquor, without causing the many injuries which the latter occasioned. In consequence of the cloth becoming yellow after being bleached, recourse was had to alternate boiling in alkaline liquors, after the immersion in the bleaching medium; but the frequent exposure of the goods, as well as of the vessels containing the bleaching liquor, caused the liberation of too much chlorine, which proved a great impediment on account of its fatal effects upon the operatives, and hence the process could not be carried out. In the meantime, however, the fact was discovered, that alkalies combine with more chlorine than water, retain it with more tenacity, and yield it more regularly to the coloring matter. The workmen now had more security; for the gas being in chemical combination with the alkali, did not escape into the atmosphere, although this combination did not prevent it from operating upon the goods. Soda and potassa were the compounds employed for this purpose; and it generally happened that every establishment had stills, carboys, and other apparatus, to enable them to prepare the bleaching liquors under their own inspection. The same custom is followed at present by many firms, especially when very fine goods are operated upon.

The liquor thus produced lost its power very rapidly, much more so than the solution prepared by impregnating water with the gas. In this predicament another effort was made, and lime was employed instead of the alkalies; but the first methods of using it, namely, of steeping or passing the goods through lime water, and then exposing them to the action of chlorine, were productive of some irregularities, which required a further improvement in the preparation. This improvement was accomplished by Mr. Charles Tennant of Glasgow, who impregnated the lime water with chlorine, and took out a patent for his *bleaching liquor* in 1798; this patent was infringed, and Mr. Tennant took law proceedings against the offenders in 1802, but the jury decided the case against him.

Another patent was granted to him in 1799, for the preparation of dry *chloride of lime*, or bleaching powder. This was more successful, as no dispute leading to legal proceedings arose as to its originality, and it has continued to be more and more extensively employed, till, at the present time, bleaching powder is the chief agent by which decoloration of textile fabrics is effected.

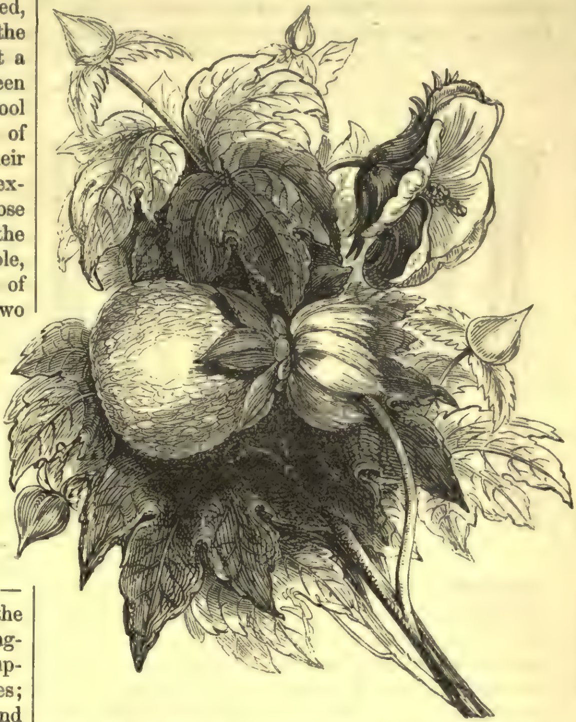
Such is a very limited sketch of the history and progress of bleaching. Attention will now be directed to the real nature of the materials, and also to the coloring matters with which they are impregnated, to show more clearly the treatment applied to the goods. Upon examination, it will be discovered at a single glance, that considerable difference exists between a sample of cotton, hemp, or flax fibre, and one of wool or silk; hence the propriety, and even necessity, of applying different chemical substances to effect their purification, at once suggests itself. On a closer examination of the nature and composition of those bodies, the fact will become more apparent. That the reader may comprehend the subject as far as possible, the whole materials which enter into the formation of clothing, and other fabrics, will be divided into two classes; namely, those which are of a vegetal nature, and such as are derived from animals. The first includes cotton, flax, and the other vegetal productions employed in the making of fabrics; the second embraces silks and wools.

In consequence of the advanced state of bleaching and printing, the fabrication of cotton goods has far outstripped all others; hence, attention will first be directed to the consideration of this substance.

COTTON.—*Coton*, French; *baumwolb*, German.—This substance is the filamentous down enveloping the seeds of several species of a plant—*Gossypium*—belonging to the natural order of *Malvaceæ*. The chief supplies are particularly obtained from four of the species; the *Gossypium arboreum, herbaceum, hirsutum*, and *Barbadense*, but especially from the second. *Gossypium arboreum* is perennial, and grows to the height of six or eight feet; the *herbaceum*, which is an annual plant, reaches the height of only two feet; the *hirsutum*, or hairy American cotton—also an annual—attains about three feet, and the *Barbadense*, or Barbadoes shrubby cotton, grows to about four feet. According to the statements of several who have devoted much attention to the cotton plant, it appears that climate exerts a very great influence upon the quality of the crop produced. It is indigenous to warm countries. Fig. 174 is a drawing of the cotton pod and flower belonging to the annual herbaceous plant—*Gossypium herbaceum*.

The ancients were acquainted with the use of cotton as a material for clothing. PLINY describes the cotton plant as growing in Upper Egypt, from which it is easily seen that his gossypium is the same as that which is thus designated at the present day. The cotton manufacture constitutes one of the largest branches of British industrial art, particularly since the application of mechanical and chemical improvements in the different processes. Cotton is of various shades, from nearly white to a deep yellow; the darkest variety comes from Siam and Bengal. This natural color is more easily removed from the fibre of cotton than from that of flax, and hence the former is bleached with greater facility than the latter. Already a short description of the old system of bleaching, particularly that followed in Holland, the most famous country for this business in bygone days, has been given; but what follows has more particular reference to the art as now carried out by the rapid process.

Fig. 174.



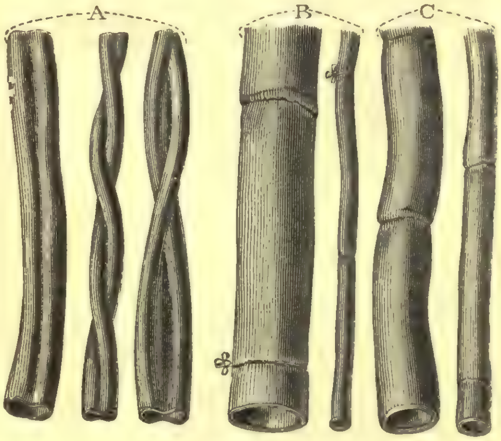
It has been stated that the natural color of cotton varies from a deep yellow to white, or colorless; so that some varieties would require no bleaching, were it not that certain other ingredients, added preparatory to their being made into cloth, render them dirty, besides imbuing them with substances which are found difficult of expulsion, and communicate more or less color. Many fabrics require no further bleaching to prepare them for receiving certain shades of color, than the removal of these accidental additions—an operation mostly performed by boiling with soap or alkaline liquors, and subsequently washing.

The fibres of cotton, as shown by the microscope, are represented in the following sketch—Fig. 175—in which the fibres of cotton and flax are contrasted. The fibres, A, are from raw cotton prepared for manufacture; the fibres, B, are those of raw flax before spinning; and the fibres denoted by C, are those of unravelled threads of manufactured flax. All the fibres figured, represent each $\frac{1}{200}$ of an inch in length, and are magnified four hundred times in diameter. They vary in thickness from $\frac{1}{800}$ to $\frac{1}{3800}$ part of an inch. It will be observed that the cotton fibres, as thus revealed by the microscope, are somewhat flat, two-edged, or triangular, and not straight, but contorted—a construction which causes the fibres to adhere to each other, and which gives warmth to cotton clothing. The fibres of flax, on the other hand, are straight notched tubes, with a smooth surface.

The substances present in cotton goods, when they enter the establishment of the bleacher, and which require to be eliminated, are—

Firstly, The organic matter naturally adhering to, or incorporated with the fibre, which gives the peculiar color. It seems, however, to have no influence on the strength of the filament, for the thread or cloth is found to be as strong after its discharge as before. This matter is slightly soluble in water, and entirely in alkaline liquids; but it happens that, on boiling many grey calicoes in lime water, the tint is rather deepened than extracted, and hence it may be hastily concluded that no decoloration takes place. Upon a closer examination, however, it will be found that the lime water takes up a resinous substance, which is more or less external to the coloring matter, especially if the solution be neutralized by hydrochloric acid; the extracted resin and coloring matter are thus set free in the shape of light flocks. The acquired tint which the goods apparently possess after such boiling, is owing to the property which lime has of entering into combination with, or disposing the elements of some organic bodies, so as to present a brownish appearance. Although lime and alkalies generally attack the goods so as apparently to abstract the coloring principle, such is not the case; and it is only after exposure to air and light, or some bleaching medium, such as chlorine or sulphurous acid, that its complete removal is effected. As remarked in the commencement, the precise nature of the change induced by those processes cannot be stated with certainty, but, from experiments performed upon pieces of cloth submitted to oxygen and chlorine in moist and dry atmospheres, the conclusion has been arrived at, that sometimes a dehydration of the substance takes place, water and carbonic acid resulting in case oxygen is used. Chlorine frequently enters into combination with the elements of the substance, producing colorless bodies which are subsequently extracted; it likewise effects the same change by dehydration, hydrochloric acid being formed. These results are produced whether the experiments be conducted with dry materials and in a dry atmosphere or not, but in the first instance its effects are slower than if water were present.

Fig. 175.



Secondly, A resinous matter insoluble in cold water, though slightly attacked by it at the boiling point. This resin is a natural component, adhering to the fibre, and its use seems to be that of protecting the other components from the influence of the atmosphere, which would ultimately destroy the coloring matter, and probably affect also the other constituents, so as to endanger the life of the plant. With the view of removing this resin, and thus facilitating the abstraction of the natural color, the operation of *scouring*, which consisted in passing the cloth through an alkaline lie, was resorted to. This practice is now almost entirely discontinued. The resin, on boiling the cloth containing it in alcohol, is completely extracted, and upon expelling the spirit at the temperature of the water-bath, it remains in the form of thin yellowish scales, soluble in potassa or soda.

Thirdly, Fatty matters are always present in cotton and linen goods; a small portion is natural to the material, but the chief portion is added to render the spinning and weaving processes more easy. These matters, if not completely removed, occasion much inconvenience, and injure the beauty of the printed goods; for, by some decomposition which occurs, they adhere with great pertinacity to the cloth, and subsequently act as mordants, as well by precipitating the agents employed for this end as the coloring substances, and hence spots and inequalities of tint in the printing are observed, to eradicate which, when once produced, is next to impossible. The grease or oily matter which drops from the machinery during the spinning and weaving, appears to be the most injurious in this respect.

Chlorine serves only to render the oily substance more permanent, for it enters into combination with it, and prevents its being acted upon by alkalies or acids. Exposure to the air, however, seems to oxidize the fatty substance, and assists it to combine and form a soap with alkalies. Sulphuric acid aids considerably in the removal of the cupreous grease from the cloth, even when alkalies and lime fail, as it forms a soluble sulphate with the metallic base, leaving the fatty acid to be assimilated with an alkali in the lie.

Fourthly, The weaver's dressing, which may be starch, flour, or size, is usually employed in the sour state, or after the acetous fermentation has taken place.

Lies were once used in this composition but are now discontinued, in consequence of their giving rise to carbonate of ammonia by the decomposition of the gluten of the flour, and when this change occurred, and the goods were exposed to the air, the fatty matters were converted into a peculiar compound, which acted as a mordant, remained insoluble upon the fabric, and was removed only with great difficulty.

Fifthly, Inorganic saline matters, some of which are inherent in the fibre, others derived from the water, and partly abstracted from, or contained in, the size used in the warp, *et cetera*. On boiling the cloth in milk of lime, an insoluble soap is formed; this, however, is acted upon by an excess of the base, and more effectually by caustic soda. Sulphates of copper and zinc are occasionally met with, but as such compounds are neutral in themselves, and are only added to neutral substances, it is not easy to say what change they bring about, or what position they occupy among the other constituents.

Sixthly, Perspiration and filth from the hands of the workmen, which are easily removed by any simple detergents.

Seventhly, Any earthy or ferruginous matters which may be accidentally taken up during the exposure of the goods in the course of bleaching. These, like the preceding, are easily removed.

If cotton goods could be prepared without employing any of the foregoing extraneous matters, and the bleacher had to deal with a fabric consisting merely of vegetal fibre, and the coloring and resinous matters naturally present in it, the operation of depurating such goods would be simple and easy; it would suffice to carry off those bodies directly, by the application of some solvent or decolorizing substance, which would abstract them *in toto*, or else destroy the coloring matter in them; or indirectly, by a modification of the above, so as to remove them partly by solvents, and partly by bleaching agents. The presence of fatty or oleaginous, and more particularly resinous matters, however, renders this operation much more complicated; for these, as already stated, resist the action of the bleaching compounds, and hence they must be removed before success can be attained in bringing the fibre to that brilliant whiteness which naturally belongs to it when freed from extraneous compounds. If the operator persevered in the application of the bleaching substance, till it, per force, penetrated to the color, then most probably the object he sought would not be accomplished; and the cloth, through the corrosive action of the acids or other bodies, would either be rendered useless, or considerably damaged. This is why so many preliminary steps are taken previous to the treatment with chlorine gas, or other means employed to remove the color; and from the explanation just given of the nature of the substances present, it is hoped that the reader will comprehend with facility what is to follow.

The rapidity of the bleaching process, as now pretty well known and understood, dates from about the year 1828, when machinery was made to supersede manual labor. To Mr. **Bentley**, of Pendleton, is due the merit of making the first efforts in this direction; and although his early proceedings were not so well adapted to command superiority during the succeeding years of rapid advancement, yet they pointed out the way in which others might follow, and greatly enhanced the value of the various machinery employed, as well in their effect as in the simplicity of their construction. In this department much is due to Mr. J. **Graham** of Manchester, for being in the foremost ranks of those who have assisted in bringing the operation of bleaching down to its present simple and almost entirely mechanical form. His machinal arrangements and speeds have been adopted by a great many of the trade, and have been found successful, inasmuch as the quantities of the chemical compounds which were generally required to execute the necessary works are considerably lessened, and the time also much shortened.

The usual routine of bleaching for madder work is the following, but when it is intended for what is termed *steam work*, fewer operations are required.

Of these, nine stages exclusively belong to the decoloration, and five to the dressing, of the cloth. They are—

1. Stamping and ending.
2. Singeing.
3. Washing or scouring.
4. Bucking, or boiling with lime water, and washing.
5. Souring, or *chemicking* in acids, and steeping and washing.
6. Scouring with caustic alkali.
7. Washing.
8. Immersion, or chemicking in bleaching liquor.
9. Souring.
10. Steeping.
11. Bucking with caustic soda or its carbonate.
12. Souring.
13. Washing and squeezing.
14. Mangling.
15. Starching and drying.
16. Calendering, folding, and stamping.

1. The first part of the work affords little interest to the chemist; but to make the subject as complete as possible, it will be briefly noticed. As soon as the goods enter the bleacher's establishment, it is necessary, to prevent confusion afterwards, that each lot should be marked with the owner's name, so that, at the termination of the work, little difficulty may present itself in delivering the goods. With this view, a person takes each piece, and stamps on one end the name of the owner with a brand of wooden letters dipped in *coal tar;* a body that remains unacted upon during the usual operations. By washing well with soap, and rubbing between the hands, however, it will ultimately be obliterated. Some finer qualities of goods, instead of being marked with this material, have the initials, or full name, inserted in some indelible colored thread, or with nitrate of silver, as the case may be.

The several pieces are then stitched end to end, in order to facilitate the subsequent bleaching.

2. This operation is, like the above, a preparatory one, and consists in singeing or burning off the loose fibres or flocks on the surface of the cloth; were these permitted to remain, they would very much injure the appearance of the bleached goods. The usual method of performing this part of the work is to pass the cloth over red-hot rollers, at such a velocity that the body of the threads is uninjured, although the loose fibres are consumed.

By another method, gas is made to serve instead of the rollers, the cloth being drawn over the naked flame. Mr. **Hall**, of Nottingham, made this the subject of a patent a few years ago, and his plan has been found to work well.

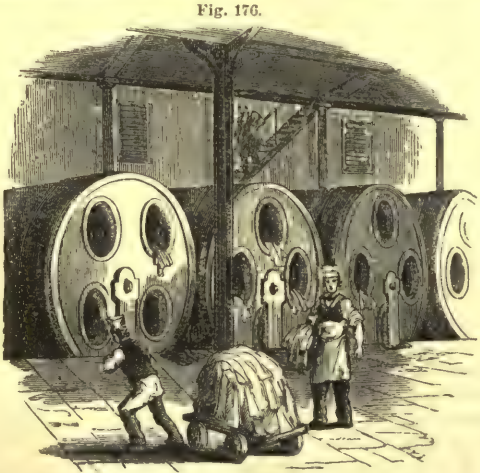
3. The next operation to which the goods are submitted, is the soaking and scouring; it is one of considerable importance, and requires some art as well as knowledge to perform it satisfactorily. Were the cloth to be thrown into water in regular folds, it might remain there a considerable period before the liquid would penetrate it; but as this expenditure of time would not answer, the pieces are drawn through a pipe, by which they are given the appearance of a rope, then coiled up into a bundle, tied together, and thrown into the cistern. Here they are permitted to remain till they get thoroughly soaked, after which they are covered with warm water of 120° or 140° Fahr., and left to rest for thirty-six hours, during which time the glutinous matter of the size enters into a fer-

mentation; this action must be checked as soon as it has advanced to the proper limit, for if it were continued, putrefaction would ensue, which would materially affect the fibre of the cloth. This process is not always followed, for it is injurious where fatty matters have been incorporated with the cloth in its texture or otherwise, as the acetic acid formed, entering into combination with such bodies, renders them insoluble in the after bucking with the lie; in consequence of this behavior the cloth appears speckled. A great many boil the goods in weak milk of lime, to clear them of all the substances soluble in this menstruum. For muslin goods, and such fabrics as are not contaminated with grease, preference is generally given to the fermentation method, on account of the perfect manner in which it abstracts the gluten. After the decomposition, the cloth is washed or scoured in a vat, either by the *dash-wheel*, or some other convenient apparatus; the time extends generally from a quarter to half an hour. This operation, which is of considerable importance to the bleacher, is performed several times during the work.

Most of the impurities of the cloth are here removed —generally from ten to fifteen per cent., according to its original state; whereas, by all the after processes, not more than 0·5 per cent. of foreign matter is abstracted.

Fig. 176 is a drawing of the dash-wheel, which consists of a cylindrical box revolving upon its axis, and divided into four parts. Each of the divisions is supplied with an opening, into which two or more pieces of cloth are introduced; water is admitted from behind, and the wheel is set in motion, causing the cloth to toss from side to side, by which the washing is performed in from eight to ten minutes

Fig. 176.



4. The boiling or bucking with alkaline liquids, has for its object the abstraction of the small portion of the fat naturally present in the fibre, and also that casually added; likewise, the removal of the residual portions of the gluten. For a long time potassa and soda lies were used for bucking the goods, until, by some happy hit, lime was introduced. Such a selection might have been made at first on the score of cheapness; but both science and experience affirm the choice, as it fulfils all the requisites in consequence of its very energetic action upon fatty matters, forming with them an insoluble calcareous soap. It is unknown who first employed it, but like every other novelty it met with its due share of opposition. Some rejected it entirely, in consequence of its destructive action upon the goods, owing to the immoderate use they made of it; others complained that it gave rise to insoluble soaps, which they could not wash away with any degree of satisfaction; and this grievance was still more complained of, when it was found that the soap united partially with the colored substances, becoming soluble in some parts, whilst it was obstinately retained in others. It was discovered that, by acting upon the soap thus constituted with sulphuric acid, it suffered decomposition, a lime salt of the acid being formed, and stearic, margaric, and oleic acids—the principal constituents of the fat or oil—being liberated; and that, by boiling the goods in a lie of caustic or carbonated alkali, those fatty acids were removed in the form of a soluble soap, and with them a great portion of the resinous and coloring matter. Still, as pointed out in the commencement, considerable quantities remain, and the shade of the cloth is deepened rather than lightened, for the reasons there assigned; but, at the same time, the resinous coating which shielded the material intended to be removed is taken up, and the chlorine has ready access to exert its greatest influence upon the cloth.

Experiments have fully demonstrated that the strength of the cloth is not injured by being boiled with lime water for two hours; it is necessary, however, that it should be of a certain strength, and likewise that the pieces of cloth should be covered over with the lie, stirred repeatedly during the boiling, and washed immediately after being taken out, in order to prevent the absorption of carbonic acid, which would form carbonate of lime on the cloth, and thereby destroy it in a great measure. It has been also observed, that ebullition in water, or in a soda lie, marking 3° Twaddle, or 1·015, at a pressure of ten atmospheres, notwithstanding that the alkaline liquor may, during the boiling, acquire double the density which it originally possessed, does not affect the goods, neither are they injured by boiling under atmospheric pressure in a lie of 1·070 specific gravity, or 14° T.; or by being immersed in a solution of bleaching powder, capable of decoloring three times its volume of a test solution of sulphindigotic acid for eight hours, and by being afterwards dipped in sulphuric acid of specific gravity 1·067 or nearly 14°; or by being steeped for eighteen hours in hydrochloric or sulphuric acid of 7° T.—*Ure.*

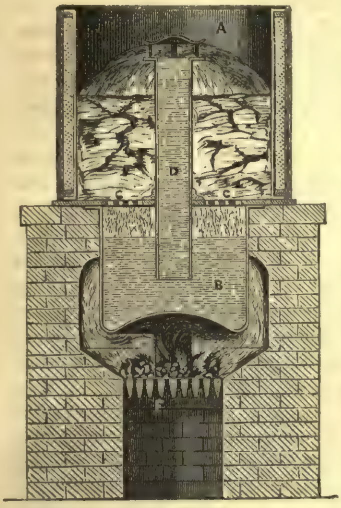
The bleachers, however, perhaps for wise reasons, never expose their cloth to solutions of the strengths above specified.

Before proceeding further, the boiler or *kier*, in which the bucking is performed, will be described. Considerable advantage accrues to the bleacher from the use of the most convenient apparatus, as in that case the danger of spoiling the goods, or of not having the operations successfully performed, is lessened. Scouring machines, or boilers, may be divided into two classes: those which are heated by the direct action of fire, or by steam, and in which the lie is in contact with the goods; and such as have the lie heated in a separate vessel by the same means as the preceding, and then made to percolate or strain through the goods in a continuous and revolving stream.

In large establishments, steam heat is the most economical, for one high-pressure boiler can execute nearly whatever boiling is to be done; but when the establishment is small, the use of steam is attended with loss, inasmuch as more heat is wasted, and a larger quantity of coals consumed, than if the open fire were applied to the boiler. Of the two classes of scouring apparatus, those which sparge the lie on the cloth in a continuous and successive stream, are more favorable to the decomposition of the fatty, and the elimination of the resinous bodies, than the others, in consequence of having a more elevated temperature acting in conjunction with the liquid; hence they are employed in nearly all cases.

The simplest of this kind of apparatus is represented in the annexed engraving—Fig. 177. This bouking or bucking kier consists of two principal parts; one, A, is the large receptacle for the cloth, and the lower part, B, is the boiler where the lie is submitted to the action of the fire. There is a communication between these two parts at C C, which consists of a strong iron or copper grating. In the middle of this grating a pipe, D, is firmly screwed; through this the lie in the lower pot ascends during the boiling. It is surmounted by a cap, by which the ascending liquid is made to spread over the goods, and return to the pot to be again heated. The upper part of this kier may be constructed of wood or sheet-iron, well riveted and joined to the lie-pot; the latter may be of copper. As the object is to have an elevated temperature, the top vessel is shaded with a casing of wood, between which and the boiler is packed sawdust, charcoal, or some non-conducting material, so that no reduction or loss of heat may be experienced by conduction or radiation. F is the grate whereon the fire which heats the whole rests.

Fig. 177.

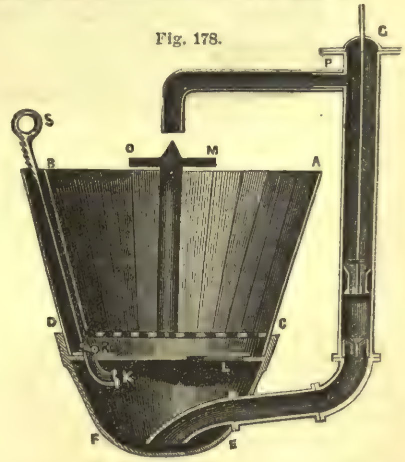


The action which takes place in this boiler is as follows:—On applying the heat, the liquor in the lower vessel does not boil till the temperature exceeds 212° Fahr., but as the pressure is less in the pipe, D, in the course of a short time the liquor contained in it reaches ebullition, and steam is generated, which rushes out at the top, whilst the expansion of the body of liquid causes a column, more heated and denser, to rise, which throws that already in the pipe out upon the cloth. In this way the operation is conducted, a continuous stream falling upon the cloth, and percolating through the grating into the boiler, where it takes up a fresh portion of heat, and reascends as before.

Sometimes the end of the pipe, D, reaches midway between the grating and real bottom of the lie-pot, and the boiling is continued as in the preceding case. Eight hours' boiling is the usual period for the completion of the first bucking, but this is sometimes prolonged to ten and even fifteen hours. At the conclusion, the spent lie is drawn off by a pipe and stopcock at the bottom of B, and the goods are removed to the scouring machine.

It may be well to notice here an improvement in the method of bucking by Mr. **Laurie** of Glasgow, and carried out by several Lancashire and other bleachers. Fig. 178 gives a sectional view of the apparatus, but still it is only a modification of the foregoing.

Fig. 178.



In this figure, A B C D is a large wooden tub, or kieve, into which the cloth is put; and which is firmly fixed, at C and D, to a copper or cast-iron boiler, C E F D, as seen in the drawing, wherein the lie is contained: it is covered lightly by a plate of the same material, a communication being made by means of a pipe, K, between it and the top vessel. A pump, G, is in connection with it, by which the liquid is raised and discharged upon the goods in the kieve through the pipe, P. M O is a metallic plate upon which the pumped lie falls, and is dispersed all over the cloth. The whole is heated by a furnace as in the preceding.

The cloth is placed upon a movable frame or rack, and introduced into the upper vessel; the fire is then lighted, and while the contents of the lower vessel are reaching ebullition, the pump is kept in action; but after the lie begins to boil, the elasticity of the vapor keeps up the current, and the pump is no longer worked. As the liquor falls through the cloth, it returns to the boiler by the pipe K, the valve, R, attached to this pipe being opened by means of the handle, S.

Fig. 179 is a front elevation, and Fig. 180 a sectional view of the kier, improved by Mr. **Graham**, of the Hartshead Bleaching and Print Works, Manchester. It is about eight feet in diameter, by six and half in depth, and is heated by steam injected through a pipe from a high-pressure boiler. The central pipe is about eight inches in diameter; it is surmounted by a cap, against which the liquor is forced by the pressure of steam from beneath, and distributed over the goods. The kier, when in use, is secured by a well-fitting cover and screws, and any excess of elastic vapor which may have accumulated during the period of bucking, which generally lasts fifteen hours, is carried off by a pipe inserted into the shoulder of the kier. Many other boilers are in use, some of which have the lie heated apart from that which contains the goods; but the liquor finds its way into these, in the same way as in those described, by means of connecting pipes.

Fig. 179.

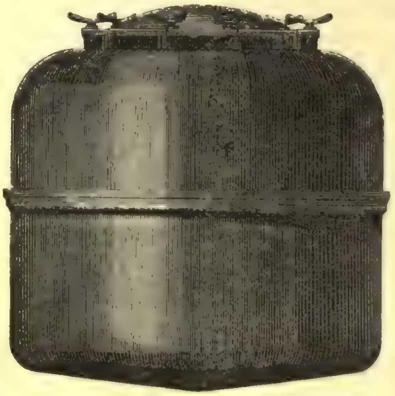
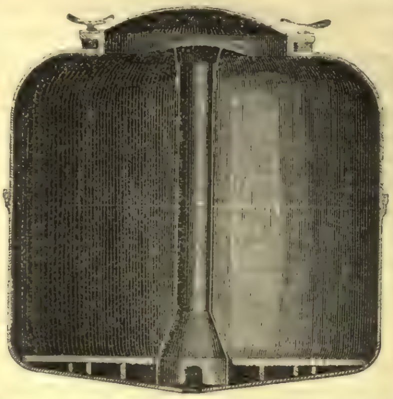


Fig. 180.



The quantity of lime employed varies; the usual allowance is about three, but some employ as much as seven per cent. of the weight of cloth. The mode of applying it, is to slake it in a separate vessel till it is of the consistence of cream; a layer of the cloth is then placed upon the perforated or false bottom, and a quantity of the liquor poured over it; these are continued, alternately quantities of cloth and lime water in succession, till the whole is introduced, after which sufficient water is admitted to the boilers, so as to have a gallon of liquor to four pounds of cloth, or thereabouts, and the operation of scouring carried on as described above.

Some bleachers employ a mixture of lime and carbonate of soda, in the proportion of fifty-five to sixty-five pounds of each to the ton of cloth, as it is said that such will scour the goods more effectually than the lime *per se*. In this case the lime becomes inert, by abstracting the carbonic acid from the soda salt, and hence the caustic soda executes the work. CLAUSSEN uses caustic soda and lime.

Latterly, steps have been taken by METZ, an engineer of Heidelberg, for the discontinuance of the boiling system to which fibrous materials, intended for or manufactured into cloth, are subjected in the present system of bleaching; he states that, from numerous experiments, he was led to the conclusion that the chief good which the boiling renders is, the expulsion of the air from the interstices of the fibre, and that the removal of oily or other substances is only the alleged or ideal benefit attending the bucking. Removing the air from the fabric or material by any other means, such as exhaustion or pressure, would be, he thinks, as effectual as the boiling, without exposing the cloth to the danger of being injured, as at present.

Figs. 181 and 182 are drawings of his pressure apparatus for expelling the air, and preparing the cloth, as effectually as the boiling in the kier; the first being an end elevation, and the second a vertical longitudinal section corresponding to it. The apparatus consists of two vessels, or receivers, of a cylindrical form, made of tin or copper plates, and fixed upon one foundation. Into the larger of these, A, the materials are introduced through the opening at the top, and after that the cover, *d*, is firmly secured by the screw, I. A false perforated bottom, C C, placed in the interior of this cylinder, may be removed at will by the aid of a handle, *p*. All the air not retained mechanically, or in combination, passes off during the filling of the cylinder with water through the pipe, O O, at the bottom, by the pipe, *f*, which opens in the interior at the cover, *d* and is joined at the other end to the indicator and regulator, H, in connection with the vessel, B. On a support running across the top of this vessel, the pump, P, and its adjuncts are fixed; and this—by means of the suction pipe, *l*, perforated with small holes at *i*, so that nothing bulky can enter—forces the water through the pipe, *n*, and passages, O O O, into the vessel, A, containing the goods, and also into any others which may be in connection with it, as is shown by the continuation of the passage in the drawing. The pump has a safety-valve attached to it, as seen in Fig. 181, at *x*, weighted by the lever, S.

Fig. 183 is a sectional drawing of the regulator and indicator mentioned in the foregoing, and denoted by H. It contains a conical valve, a', which rising, presses against the lower end of the piston, c'; this works in the socket, *d*, above which it has a collar, e', whereby it receives the pressure of the helical spring, f'; this causes it to butt against the top, b', screwed into the cylinder, and formed with a central opening for the passage of the piston-rod, c', graduated externally to show the degree of internal pressure; l' and i' show the corresponding parts in Figs. 182, 183. Before the air can escape, it must raise the valve, a', which cannot be accomplished unless the force determined by the adjustment of the spring is attained; hence it must escape by the pipe, *h*, shown in the two preceding figures.

Fig. 181.

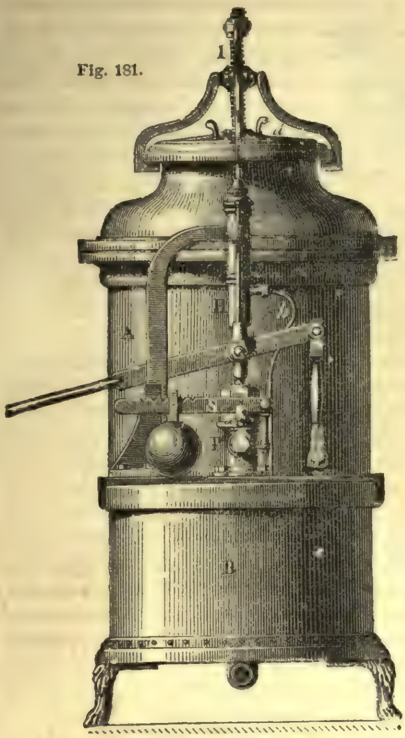
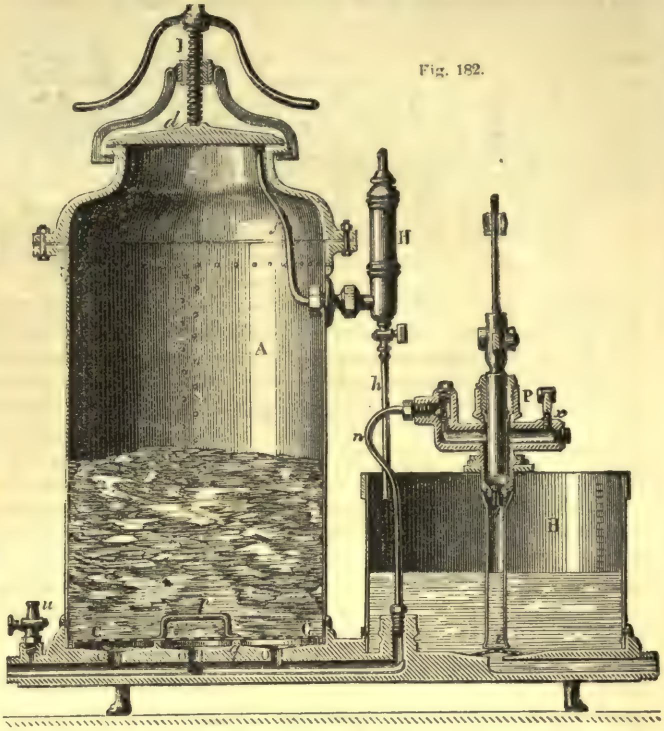


Fig. 182.

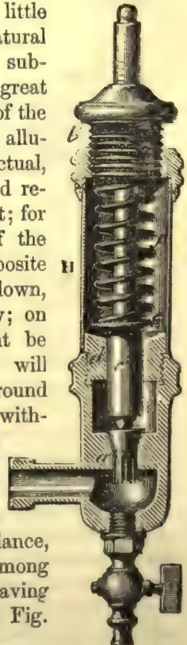


The operation is very simple. The indicator is regulated so as to maintain a pressure inside the vessel, A, sufficient to expel the whole of the air, after which the material is said to be fit for the bleaching agents. The patentee asserts that a continuation of the pumping, even after the expulsion of the air, has a beneficial cleansing effect, and that a little lime water may be employed with advantage on many occasions.

Having scoured the cloth for a sufficient length of time, it is taken out of the boiler and brought to the *dash-wheel*, or other machinery for washing already described, and there freed as much as possible from the calcareous and organic substances disengaged during the bucking in the boiler; it is then passed on to the squeezing rollers, to remove all the impure water from it, but if these are in connection with the scouring machine, this will be unnecessary.

When the cloth is to be passed between rollers, all the pieces are stitched end to end, if this be not already done, and deposited in a vessel of water at the other side of the machine. The pieces of cloth are tossed to and fro with such rapidity in the dash-wheel, if this be used, that they get entangled; so much so, that unless they were unravelled the cloth could never pass between the rollers. At one time, these intricacies into which the cloth was thrown were cleared away by two workmen, but the water-tank now serves the same end, and the labor heretofore expended on that operation is saved. One end of the cloth is introduced between the cylinders, and after being deprived of the water in its onward movement, the attendant folds it at the other side upon a table or convenient stage. The rollers generally make about twenty-five revolutions per minute, in which time three pieces, measuring together eighty to ninety yards, are pressed.

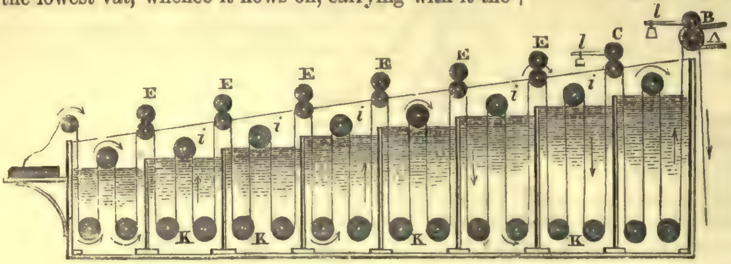
Fig 183



Washing the cloth before and after the bucking is a matter of no little trouble, in consequence of the natural impurities, the lime, and other substances being retained with very great adhesive affinity in the interstices of the cloth. The dash-wheel, to which allusion has been made, is very effectual, but is limited in its operations, and requires some skill in its management; for if its motion be slow, instead of the cloth being thrown against the opposite part of the wheel, it will slide down, and no detergent effect will follow; on the other hand, if the movement be very rapid, the centrifugal force will cause the goods to circulate around with the periphery of the wheel, without ever falling against the sides as intended.

A very efficient and economical washing medium, especially where water is not in very great abundance, has been in use for some time among the Lancashire bleachers, an engraving of which is given in the annexed Fig. 184.

It consists of a number of vats of different depths, full of water, and supplied with a constant stream, which flows into the uppermost and thence into the next, from this to the third, and so on till it reaches the lowest vat, whence it flows off, carrying with it the impurities of the scoured cloth. Within each of these vats or tanks a guide and tension roller, K K, is placed, and also at the surface similar ones, *i i*, are supplied; the rollers, E E E, are merely employed to squeeze the impurities out of the cloth as it passes out of the vat. Motion is communicated to the whole through the cylinders, A B and C D, which act also as squeezing and traction rollers, and are kept in close proximity by means of levers, *l l*. By the use of this machine a considerable quantity of cloth is washed in a very short time, but the tension to which it is exposed is so great that the pieces are considerably lengthened, oftentimes as much as four per cent. It is evident that, when very fine goods are operated upon, this cleansing machine will not answer, and that recourse must be had either to the dash-wheel or some other contrivance, which does not exert any such influence upon the goods.



Before leaving this department of the washing, it will be well to give the reader a cursory description of a machine recently patented by Mr. BRIDSON, of Bolton-le-Moors, Lancashire, as it possesses considerable merit over those hitherto in use, and at the same time retains the chief recommendation—*simplicity*. It is represented in the annexed figures:—

Fig. 185 is a longitudinal, and Fig. 186 a transverse section of this machine. The body of the *washer*, A, is a cast-iron tank, kept half full of water; through the sides of this tank two horizontal transverse shafts, B C, are passed, and carried on bearings in the two opposite side plates; they project from the side at B C, to carry corresponding spur-wheels, one of which is represented at E. By means of an intermediate driving shaft, which carries a wheel gearing into those upon B and C, the latter are moved in the same direction. B, C, have each a pair of discs, H I—Fig. 185—for holding the diametrically opposed parallel bars, J, which form the winces or revolving frames for acting upon the goods in the washing movement. The central shaft and wheel give motion to another superior wheel, K, fixed upon the axis of the lower roller, L, which, by moving in contact with another, squeezes the cloth. These rollers are of considerable size, and are supported by a pair of vertical standards, M, carried on a cross bar on the top of the cistern, which also bears a small standard for supporting the projecting end of the roller. The bottom roller is fixed, but the upper one is movable; means are furnished for adjusting them in the central vertical slot of the standard, M. In the longitudinal section, the course of the fabric, O, is shown round the guide roller, P, thence between the pair of nipping rollers, Q, set in bearings at one side of a division piece, R, and adjusted by handwheels and screws. After the cloth leaves these, it winds under the guide roller, S, and passes along between the first pair of vertical guide bars, T, then round the under side of the flat wince at the opposite end of the cistern; and returns in a parallel direction, moving in the same way over the bar, J J, of the discs, H I, and in the space between the second pair of division bars, T. In this way it continues its course, as seen in the transverse section, till it finally returns in contact with the wince bars, and passes up from beneath the guide-roller, U, set at the water level at the delivering end, over the external cylinder, V, and is delivered through the squeezing rollers, L, dry and clean. Two lines of fabric are operated upon at the same time, and therefore they follow the same course as that described.

Fig. 185.

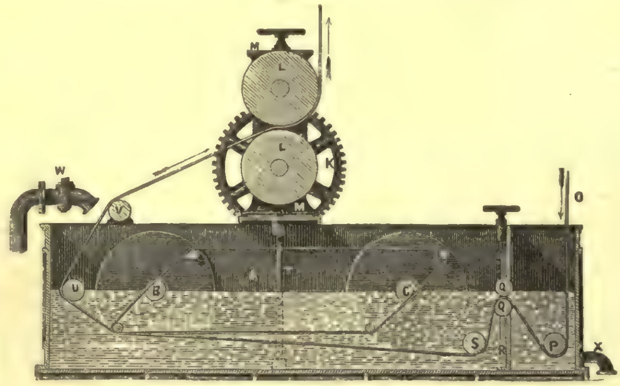
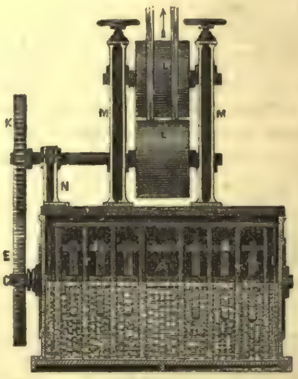


Fig. 186.



The efficacy of this machine lies in the flapping or beating which the cloth receives from the revolution of the winces, during the time from its entrance till it passes out by V. This shaking and flapping or beating of the cloth is readily comprehended from the drawings; for at that period of the revolution of the discs, when the set of winces and their shafts are in a horizontal position, the passing lines of fabric are in contact, and by the time that the discs have made the one-fourth of their revolution, the lines of cloth are sundered by the diametrical extent of the wince bars. The stroke of the cloth on the surface of the water, and also the agitation of the line immersed to bring it to the surface, have very great effect in detaching all the adhering impurities from their position in the fabric, and rinsing them out of the goods. As the cloth emerges from the water it is stretched to its entire width, and must, consequently, raise a considerable quantity of water with it, which percolates, or is otherwise thrown off, but which serves to drench the cloth and free it from extraneous matters. According to the strength of the goods, other wince bars may be secured into the discs, so as to increase the flapping of the cloth against the water. By having the roller, C, fitted in slots instead of fixed bearings, the necessary tension is kept on the cloth by the action of the india-rubber springs at the ends of the shaft, and the drag occasioned by the squeezing rollers, L, as well as that tension of the cloth which arises only between the guide rollers, U, and these squeezers, compensates for any irregularity when the fabric leaves the water at U. The nipping rollers, Q, regulate the tension of the cloth, as the tendency of the machine is to slacken the strain during its passage. Such a mode of regulation is indispensable where light and heavy goods are operated upon. Water enters the machine by the pipe, W, the flow being directed upon the emerging fabric as it passes up for the last time in its way to the squeezers, so that any floating impurities which may adhere to it are carried back. The foul water of the tank is discharged at the other end at X, but its position is immaterial, for the clean water, after it falls off the emerging cloth, gets mixed with the great body of the dirty water in the tank.

After the first bucking in the lime water and washing, the cloth is either submitted to a second operation in the same for twenty or twenty-four hours, and then washed, or subjected to the next operation.

5. The immersion in the acid solution, or the *souring*. This portion of the work is sometimes termed *chemicking*. A gallon of strong sulphuric acid is added to twenty-five or thirty gallons of tepid water, and the whole agitated so as to intermix them thoroughly. This solution will have a density of from 1·047 to 1·040, and will contain from 6½ to 7 per cent. of oil of vitriol. Many persons employ a very much weaker acid liquor, but prolong the time of immersion; the above solution, however, will not injure the fabric, as may be observed from the statement at page 304; the operation may, if considered advantageous, be modified, and a weaker souring-bath used. If it succeeds in decomposing the lime soap, the certainty of having the whole of the sulphate of lime formed dissolved out by the weak liquor, is greater than if the solution were concentrated. The time during which the goods are permitted to remain in the acid or souring-bath is generally four hours; but this is varied by circumstances, such as those mentioned, or by similar ones. After the souring, the goods are passed on to the machine, to free them from any acid that may have adhered to them, and also from any sulphate of lime, or lime salts, formed by the acid used during the decomposition of the lime soap.

6. and 7. This being done, the cloth is next submitted to a bucking in soda lie, made by adding about two pounds of crystallized carbonate of soda, or about three quarters to one pound of the dry carbonate to milk of lime, and stirring in order to causticise it, allowing the precipitated carbonate of lime to deposit, decanting off the liquid, and mixing it with from five to ten gallons of water, according to the strength of the liquor to be used. Although pounds are here mentioned, in the large bleachworks the operations are conducted on such a scale that hundredsweight of the alkaline carbonate are deprived of their carbonic acid; but the proportion of alkali in the bath for bucking the goods, nearly always remains the same as above mentioned. It is customary, by way of improvement, to add about forty pounds of resin to every hundred pounds of soda ash, and to employ this mixture diluted as above, but without separating the carbonic acid from the alkali as in the preceding. The resinous soap thus formed is said to act with greater vigor upon the coloring matters and other impurities of the cloth, than the alkali *per se*, as it enters into a soluble double combination which is removed with facility. The period of boiling with this lie extends to eight or nine hours, and after this time it is submitted to the washing machine, till all the soap formed with the fatty acids and any traces of alkali are removed. In case carbonate of soda and resin are taken, as described, the boiling is sustained during fifteen hours. This constitutes the seventh operation.

SECOND STAGE.—The preceding operations prepare the fabric for the second division of the bleaching process, which is by far the most difficult of the two. Bleaching powder is the substance which is now almost universally employed for discharging the color from the cloth, after the bucking, souring, and washing already described. When this substance is used, chlorine combines directly with the coloring matter, giving rise to a white compound, hence the bleaching properties of chlorine, and those bodies from which it may be easily liberated. Many persons assert that it is the hypochlorous acid of the bleaching powder, supposed to be so easily set free by dilute mineral acids, and even by exposure to the atmosphere, which is so very effectual in decomposing the coloring matter in the fibre. It acquires its great power, it is said, from the facility with which it is decomposed, evolving first chlorine and oxygen, the former of which assimilates hydrogen from the coloring matter, or from water, and forms hydrochloric acid, either leaving the subject colorless, or in case water is decomposed, yielding oxygen, which, by its union with one of the elements of the substance, or the whole collectively, effects the purpose in view. The Editor, however, dissents from the hypothesis, firstly, because he has proved by experiment—as will be seen under the proper head—that bleaching powder is not a hypochlorite of lime, but an oxychloride of calcium, a compound analogous in constitution to binoxides of hydrogen, calcium, and the like, thus:—

$$\underbrace{H\left\{\begin{matrix}O\\O\end{matrix}\right.}_{\text{Binoxide of hydrogen.}} \quad \underbrace{Ca\left\{\begin{matrix}O\\O\end{matrix}\right.}_{\text{Binoxide of calcium.}} \quad \underbrace{Ca\left\{\begin{matrix}O\\Cl\end{matrix}\right.}_{\text{Oxychloride of lime, or bleaching powder.}}$$

It is a point deserving of some consideration, whether it would be more advantageous to bleach the goods by the above compound, or to employ the chlorine in a free state, either as gas or dissolved in water. Past experience might be supposed to give a decisive answer to this question; for, as was already noticed, the first bleachers by chlorine employed it in the latter way, and it caused very serious injury—so much so that it was discontinued. It is evident, however, to all who have a knowledge of the element under consideration, that this injury did not arise from any want of its characteristic power; on the contrary, the failure must be attributed to the method of its application, which permitted the gas to escape, thus producing injurious effects upon the workmen, and preventing them from executing their work, in addition to the damaging of the cloth. PERSOZ is decidedly of opinion that it would be preferable to employ chlorine in the gaseous state, since its bleaching effects upon the cloth would be exerted at once, without any of the subsequent processes and injurious effects upon the tissues, which are experienced when bleached by chloride of lime. He suggests a very eligible means for preventing its deleterious action on the workmen, by merely fitting up in the bleaching works a long funnel, which must be filled with chlorine gas; the pipe from the gas generator being introduced at the lower part of the funnel, so as to gradually displace the air. At the base of the funnel there should be a shallow vessel of water, to absorb any hydrochloric acid which may be formed. The pieces of cloth to be bleached might be introduced into the funnel through a slit made at the top of one of the sides; and by proper contrivances they would be made to circulate in the interior, so as finally to emerge at an orifice opposite to the entrance. Both these openings might be closed by water-lutes, to prevent any escape of the gas.

Notwithstanding that the goods, if subjected to this operation, are bleached with great promptitude, and with results which leave nothing to be desired, yet the necessity of preparing the chlorine on the premises involves some expense and trouble—much more so than if it were generated in connection with the manufacture of soda.

Bleaching by means of chlorine water was practised, till about twenty years ago, in many parts of France, especially in the department of the Oise; but it is now entirely abandoned, as well on account of the great expense of erecting troughs or cisterns for holding the liquid, as in consequence of the disagreeable emanations that proceeded from it when submitted to the usual pressure, and which could not be done away with.

It might be in consequence of these expenses, compared with the remarkably cheap rate at which the manufacturer of sulphate of soda from common salt can prepare oxychloride of calcium, that the latter is now used on all occasions.

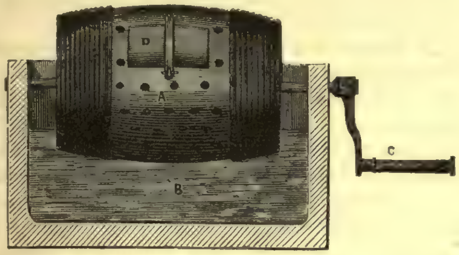
This substance, although it contain the element which destroys the organic color in the cloth, exerts but a very feeble action upon the goods, unless some other body reacts upon it, so that chlorine may be liberated. When cloth is immersed in a solution of bleaching liquor, even exposure to the air afterwards will be sufficient to disengage chlorine, on account of the carbonic acid in the atmosphere forming, with the calcium and oxygen of the compound, carbonate of lime; thus isolating chlorine. These changes, however, take place slowly; and exposure to the air is seldom or never resorted to by the bleacher; sulphuric or hydrochloric acids are preferred since they decompose the bleaching compound more rapidly and effectually. The annexed equation explains this—

$$\underbrace{Ca\left\{\begin{matrix}O\\Cl\end{matrix}\right.}_{\text{Bleaching powder.}} + \underbrace{H\,O\,S\,O_3}_{\text{Sulphuric acid.}} = \underbrace{Ca\,O, S\,O_3}_{\text{Sulphate of lime.}} + \underbrace{H\,O}_{\text{Water.}} + \underbrace{Cl}_{\text{Chlorine.}}$$

As bleaching powder does not destroy the color of the cloth, it might be supposed that the immersion of the fabric in a concentrated solution of it would not be injurious; experience proves, however, that this is not the case, for a piece thus impregnated will very soon crumble into powder, notwithstanding that it does not appear at first to be injured by the contact. This result is more rapid according to the degree of concentration of the liquid, up to a certain limit, the temperature applied, and the duration of the digestion. Hence it is of great importance to the bleacher to know accurately the strength or density of the bleaching liquid, the temperature to which it may be raised, and the time of immersion which the cloth can withstand without injury. The cause of the injurious action of the bleaching body upon the cloth is attributed by PERSOZ to the fact, that the fibrous as well as the coloring matter present is an oxidizable substance; and that, when the oxygen is liberated in a too concentrated state, it unites with the fibre, producing an oxide, and completely destroying the texture. As a parallel instance may be stated the effect of chlorine upon a solution of arsenious acid and indigo; when concentrated solutions of chlorine are brought in contact with these substances, both are fully oxidized, the metallic acid being converted into a higher state of oxidation—arsenic acid—and the latter deprived of its color. If both be mixed, and the mixture treated as above, it is impossible to state which has the more powerful affinity for the oxygen; but if the oxidizing agent be added sparingly, or in a sufficiently diluted form, the arsenical compound will then be converted into the higher state of oxidation, whilst the indigo remains unaltered. Thus it is also with the coloring and fibrous matter of the cloth; when the solution of the bleaching body is applied in a sufficiently diluted state, then the coloring matters, owing to the greater affinity they have for the decolorizing element, will take it up, leaving the other uninjured; on the contrary, if the liquid be concentrated, and the cloth be immersed in it at a boiling heat or under pressure, the results will be as before stated.

From these facts it may be concluded, that if it were possible to ascertain the weight of the coloring matter in the cloth, and if it could be equally exposed to the action of the bleaching agent, then the quantity of the latter required to decolorize or remove the former, without in the least affecting the tissue, could be apportioned with perfect accuracy. The bleaching powder is invariably employed in a state of solution which can readily be reduced to that density necessary for removing the coloring matter without the fibre being acted upon. Its solution is effected in stone vats, wooden vessels being too rapidly attacked by it. To render its liquefaction more rapid and complete, a contrivance, such as that represented in the annexed cut, Fig. 187, transcribed from Persoz, is employed. In this figure, A represents a cask placed immediately over the vat, B, containing the liquid to be used as the solvent; it is traversed by an axis, at one of the extremities of which is a winch, C.

Fig. 187

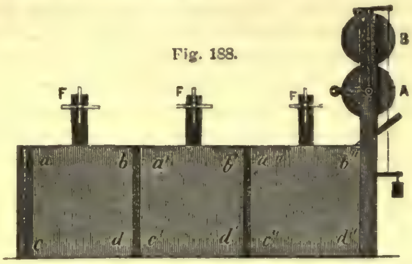


This cask dips from four to six inches into the water in the vat; it is pierced with a number of holes, from one-half to an inch in diameter, and contains a large opening, D, in one of its staves, closely covered over, serving for the introduction of the dry bleaching powder, together with some flints. The opening, D, being shut, the cask is put in motion by turning the winch, C, attached to its axis, and the flints or other pebbles, rubbing against each other, bray and pulverize the bleaching powder so as to promote its solution very rapidly. As it is of importance that the latter should be clear and transparent, it is allowed to rest till such substances as are held in mechanical suspension fall to the bottom. Without this precaution the goods are in danger of being seriously damaged, in consequence of the particles which are often found in commercial bleaching powder, and consisting of a basic chlorate, or some other compound not yet fully examined, being taken up in the cloth; these, when removed to the acid-bath, will be decomposed with the evolution of so much chlorine or chlorous acid, or oxygen, as to produce holes in those places with which they had come into contact, the fibre being completely destroyed. Muslins, and such cloths as have an open texture, are very liable to this injury, if due care be not taken to prevent it. Schwartz refers to the chlorine disengaged from the compound as the cause of this; but Persoz differs from him upon the ground that muslins may be exposed to gaseous chlorine, *per se*, or to a clear solution of the bleaching material, without being in the least deteriorated. The latter chemist attributes the injury to the forementioned particles, having found that, if bleaching powder be washed till all soluble matters are extracted, an insoluble residue is obtained, mixed with more or less lime and carbonate of lime, which, when treated with hydrochloric acid, generates one of the most energetic oxidizing bodies; and when this is spread upon the fibre, and then the latter immersed in sulphuric acid, it is burned in numerous places. The necessity of having a clear solution of the bleaching powder being thus demonstrated, the next point is to dilute it sufficiently, so that it may answer the requirement of the operator, and be adapted to the goods which are to be exposed to its action. This density of the liquor is variously estimated, being regulated according to the strength and firmness of the goods; it generally ranges from 2° to 5° Twaddle; or it is so prepared that it will bleach twice its volume of a test solution of indigo. In the event of weak liquors being used, the effects are much slower than with more concentrated ones; the bleacher, however, contents himself with the assurance that there is less risk of injury by the use of the former.

Having spoken so far of the effects of the chlorine and its mode of action, reference will be now made to the

8th and 9th Operations.—The eighth operation is the immersion in the bleaching liquor. The strength of the solution being regulated, the cloth is thrown into loose folds, and immersed in it for a period of six hours. After it is thoroughly saturated with the liquor, it is abstracted, and immersed in the steeping vats, where it is left for six or eight hours; after which it is introduced into the acid liquor, prepared so as to liberate the bleaching element to exert its influence upon the goods. This constitutes the ninth process. But instead of the preceding, many adopt a somewhat different course. Sometimes the cloth is placed in a copper boiler, similar to those described under scouring, and the bleaching liquor is passed through it in the same way that the lie is circulated in the bucking; this method, however, is objectionable, as the cloth is liable to be only partially decolorized; and it is exposed to the great danger of being injured by the boiler. The cloth is occasionally immersed in the solution for the proper period, and then left to remain exposed in the atmosphere of the room for some time, during which carbonic acid is absorbed, and the chlorine liberated to act upon the coloring matter of the cloth. After a certain time the goods are plunged into the acid solution, and here the whole of the bleaching element is set free. Again, many proceed by steeping a suitable quantity of cloth in a vessel adapted for the purpose, over which a roller is fixed. When the cloth has been immersed in the liquor for thirty or forty minutes, it is passed over the roller and suspended above the vessel till the solution ceases to drip off; it is then removed to the sulphuric or hydrochloric acid bath, over which it is hung, and the goods unrolled into the acid. Another process frequently resorted to is the following: The cloth is placed for some hours in wooden troughs—Fig. 188—lined with lead, *a b c d*, *a′ b′ c′ d′*, *a″ b″ c″ d″*, which are filled with liquid oxychloride of lime, and over which rollers, F F F, are fixed, for the purpose of communicating motion to the pieces, so as to increase their surface of contact with the solution. On withdrawing the pieces, they are passed between the squeezing rollers, A B, placed on the side of one of the end vats, and the excess of the bleaching solution returns into the vat, *a''b''c''d''*, by an inclined plane which is immediately under the rollers.

Fig. 188.



When it is desirable to perform the bleaching rapidly or continuously, a concentrated solution of the lime salt is taken, sufficiently so to destroy the fabric were it to remain in contact with it for any length of time; and into this the cloth to be operated upon is introduced for a certain period, prolonged or abridged according to the strength of the solution, and afterwards passed between a pair of squeezing rollers, again re-immersed and afterwards pressed, till the fibre gets thoroughly imbued with the liquor. At this period the cloth is thrown into the acid-bath for the purpose of liberating the bleaching agent; and as more chlorine is disengaged in this case than when the solution is weaker, the tank is covered over to carry off the excess of the gas, so as not to obstruct or injure the workmen.

The operations of bleaching by this method are much more dangerous to the cloth, in consequence of the density of the liquor, than when more dilute solutions are employed; and notwithstanding that every care may be bestowed upon the operation, it sometimes does not preclude injury from this source. The benefits which accrue from the adoption of concentrated solutions are, as was before stated, a rapidity and regularity of execution which are not usually the result of the other system; but, according to **Persoz** and others, by elevating the temperature of the weak liquor to 70° or 80° Fahr., the goods would imbibe it, and the water contained in the pores of the cloth would be displaced, in consequence of the difference between its temperature and density and that of the bath. The sour or sulphuric acid bath is of the same strength in this case as in the foregoing instance, where it is used after the scouring with lime water. Eight gallons of commercial sulphuric acid are thoroughly mixed with two hundred of water: sometimes a weaker bath is made, and only one gallon and a quarter of the acid is proportioned to three hundred of water. Both these liquors, although decidedly of a sour taste, are too dilute to be injurious to the goods under any circumstances likely to attend them in the bleacher's hands. The effect of the acid during the period of immersion, which usually lasts four hours, is the same as shown in the second formula, page 310.

10. After the action of the acid has been exercised upon the goods, they are thrown into the steeping cisterns, and allowed to remain there eight or ten hours; they are then thoroughly rinsed, and any sulphate of lime formed upon them eliminated. Portions of the coloring matter are by this means entirely removed, while others are only modified in their constitution.

11. To separate the decomposed coloring matter, the cloth is boiled in a lie of carbonate of, or caustic soda during eight hours, in the same way as has been already mentioned. Sixty pounds of carbonate of soda, rendered caustic by maceration with quicklime and water at a boiling heat, is the quantity of alkali proportioned to two thousand one hundred pounds weight of cloth; and also to every boiler of one ton capacity. After this operation has terminated, if the cloth is not sufficiently white, it is submitted to one, two, or three subsequent immersions in a bath of the lime solution, then in acid, and again washed and reboiled in the soda lie, till the proper decoloration has resulted. The density of the liquors employed diminishes from the first immersion, according as the cloth is depurated.

12. Finally, it is passed through a bath of sulphuric or hydrochloric acid, to prevent the recurrence of a more or less yellow color, contracted by the action of the air upon the resinous matter of the cloth, which is only temporarily decolorized. This substance is insoluble in alkalies, but is dissolved by acids with the aid of heat. Besides the effect of dissolving the resinous substances, any traces of metallic oxides, such as iron, alumina, or lime, which may be present, and unless removed would materially affect the printing of the goods, are so modified that they can be entirely separated in the subsequent washing to which the goods are submitted.

13. Unless this final washing is thoroughly executed much injury may arise, in consequence of portions of the sulphuric acid being retained; for during the drying it will be so far concentrated as to act upon the fibres of the cloth, and in some measure destroy their quality.

So far as the removal of the coloring matter from the cloth is concerned, the foregoing details specify the principles upon which the operation is based, and likewise the practice corresponding thereto, as followed in many of the most noted establishments in this country. Various other methods are, however, adopted in many establishments, differing widely in some instances from those described. What is here alleged of English bleachers, may be said with greater truth of the French and others, who carry on a considerable business in this department. It is, therefore, impossible to give the variety of systems of manipulation as now practised; and, indeed, were such presented to the reader, it would not be of any material advantage to him, since the processes are seldom based in the slightest degree upon fixed principles. However, to give some idea of the different methods of operation, two are selected: one by M. **Grean** of Froyes; the other, which is usually followed, and which harmonizes with the process already described, is designated *American bleaching.* Both are extracted from **Persoz**'s excellent work on dyeing.

THE GREAN PROCESS.—*First stage— Scouring.*

The goods are—

1st. Immersed in a soda liquor of two alkalimetric degrees, containing six-tenths of a part of pure soda to three hundred parts of water, or one part of soda at 60° to three hundred parts of water, during forty-eight or fifty hours.

2d. Fulled and washed.

3d. Submitted for twenty-four hours to the action of a first lie of caustic soda at twelve alkalimetric degrees.

4th. Fulled and washed.

5th. Immersed for half-an-hour in a hydrochloric acid bath, formed of one part of acid to twenty of water.

6th. Fulled and washed.

7th. Submitted for twenty-four hours to the action of a lie of caustic soda, at nine alkalimetric degrees.

8th. Fulled and washed.

9th. Immersed in the hydrochloric acid bath, as in operation No. 5.

10th. Submitted for twelve hours to the action of a lie of caustic soda at 6°.

Second Stage—Decoloration.

11th. Immersed twice successively, for three hours each time—namely, 1st, In a bath of bleaching powder at 1·5° of the chlorometer; 2d, In a bath of the same material at 1° of the chlorometer.

12th. Submitted for four hours to the action of a warm bath of caustic soda at 4° of the alkalimeter, maintained for two hours in ebullition.

13th. Immersed in a hydrochloric acid bath, similar to those of operations 5 and 9.

14th. Fulled and washed.

15th. Immersed for three hours in an oxychloride of calcium bath at three-fourths of a chlorometric degree.

16th. Worked in a hydrochloric acid bath, composed of one part of the commercial acid to three hundred parts of water.

17th. Lastly, perfectly fulled and washed.

M. **GREAN** was the first to lay down, as a principle, that the immersion of the fabrics in the bleaching solution should only take place when they are deprived of all the fatty matters. It will also be observed that, in his process, the scouring operations, all done on scientific principles, tend to gradually saponify the fatty substances, and to set at liberty, by the immersions in hydrochloric acid, the fatty acids which they contain, and which, by combining with the resinous bodies, promote the solution of the latter in the alkaline lies, which always follow the acid immersions. Lastly, the process under consideration has this further peculiarity, that the goods, on being taken from the bleaching solution, instead of being treated with an acid which sets the chlorine at liberty, are boiled in a soda lie, which has the effect of producing a double decomposition, and, finally, of bringing the fabric in contact, at an elevated temperature, with an oxychloride of sodium, which contains, in excess of base, all the lime displaced by the lie.

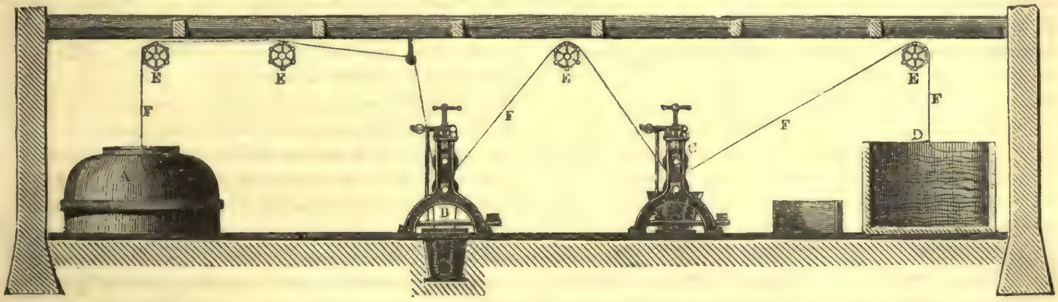
AMERICAN PROCESS.—*First Stage—Scouring.*

The unbleached pieces receive:—

1st. A lixiviation with lime for from twenty to twenty-four hours; thirty-six pounds of lime to one thousand pieces of unbleached cloth, three-quarters of a yard wide, and instead of water, the residue of lie No. 3.

2d. A washing and rinsing.

Fig. 180.



3d. A second lime lixiviation, of the same duration and composition as the first.

4th. A washing and rinsing.

5th. An immersion in tepid sulphuric acid at 1°.

6th. A washing and rinsing.

7th. A lixiviation with carbonate of soda—formed of the residue of lie No. 12, adding about two pounds of carbonate of soda for each thousand yards of cloth, three-quarters of a yard wide.

8th. A washing and rinsing.

Second Stage—Decoloration.

9th. An immersion of some hours in a solution of bleaching powder, so diluted that it does not give an indication by the areometer, and when saturated with an acid does not sensibly disengage chlorine.

10th. An immersion in hydrochloric acid at 2° AB.

11th. A washing and rinsing.

12th. A second lixiviation in carbonate of soda for twenty-four hours. To the quantity of water required for the lixiviation of a thousand yards of calico, are added about nine pounds of the carbonate.

13th. A washing and rinsing.

14th. A second immersion in hypochlorite of lime, similar to operation No. 9.

15th. A second immersion in acid at 2° AB, similar to operation No. 10.

16th. A thorough washing and rinsing.

In the continuous system of bleaching, the several operations already described are essentially the same; but the bath and other requisites are so arranged, that the work may be continued almost regularly. It would require too much space to enter upon a disquisition relative to the merits of the machinery or a detail of the arrangements, but, to satisfy the curiosity of the reader, he is presented with the annexed sketch of the apparatus and explanations, kindly supplied by Mr. JOHN

GRAHAM, the eminent bleacher and calico-printer of Manchester, and from the perusal of the preceding details the whole will readily be understood.

Fig. 189 represents the arrangements. A is the boiler or kier, which may be similar to either of those described; B is the scouring machine; C, the souring and chemicking machine; and D, the steeping cistern. The course of the cloth from the boiler to the steeps, over the carrying winches, EEEE, and through the various machines, is indicated by the line, FFFF.

For the most part, the alkalies used for scouring the cloth after the lime and bleaching powder have exerted their power upon it, are employed in the carbonated state, and mixed with a variable quantity of resin for the reasons before assigned. In like manner, the use of sulphuric acid is not so frequent now as formerly, preference being given to the hydrochloric. Not only does this acid form a more soluble salt with the lime—chloride of calcium—which may be washed out with greater facility than the sulphate, but it is said, with very great propriety, that it supplies the place of more or less bleaching powder; for, as PERSOZ states, if two equal portions of bleaching powder, not newly made, be taken and dissolved, and the quantity of chlorine in each be determined by means of a test liquor made of equal weights of arsenious acid, one being dissolved in sulphuric and the other in hydrochloric acid, the per centage will be higher in the sample tested with the chlorarsenical solution than in the other. This result cannot be distrusted, when it is considered that the bleaching powder always contains more or less chlorate and other basic salts, not fully investigated, but which are more highly oxidized; and these, upon being decomposed by the hydrochloric acid, evolve the chlorine of the acid, whilst the hydrogen enters into combination, thus:—

$$\underbrace{\mathrm{Ca\,O,\,Cl\,O_5}}_{\text{Chlorate of lime.}} + \underbrace{\mathrm{6\,H\,Cl}}_{\text{Hydrochloric acid.}} =$$

$$\underbrace{\mathrm{Ca\,Cl}}_{\text{Chloride of calcium.}} + \underbrace{\mathrm{6\,H\,O}}_{\text{Water.}} + \underbrace{\mathrm{6\,Cl}}_{\text{Chlorine liberated.}}$$

Chevalier CLAUSSEN'S patent process for bleaching is an economical, quick, and safe method. It consists in steeping the cloth to be bleached, first in a solution of carbonate of soda, and then in a solution of oxychloride of calcium, when double decomposition takes place, oxychloride of sodium being formed in the solution, and carbonate of lime in the cloth; the latter is decomposed into carbonic acid gas and muriate of lime, when the cloth is soured in a solution of hydrochloric acid. When goods are to be dyed turkey-red, or similar dyes, or linen is to be bleached, lime and hydrochloric acid are sometimes injurious; in this case, Chevalier CLAUSSEN employs oxychloride of magnesium and sulphuric acid instead. The magnesian salt is produced by double decomposition of two parts of sulphate of magnesia dissolved in twelve parts of water, and one part of bleaching powder dissolved in twelve parts of water, mixed together; sulphate of lime precipitates, and the supernatant liquor is oxychloride of magnesium. For goods to be printed madder colors, or to remain white, the following is CLAUSSEN'S process, as used by Messrs. HIGGINBOTHAM and SONS, Glasgow:—

1. SCOURING.—Boiled two hours in caustic soda, 1° T., to which is added five per cent. of caustic lime; then
Steeped in carbonate of soda, 2° T., until well soaked.
Soured with hydrochloric acid, 3° T.
Rinsed in water.

2. BLEACHING.—Steeped in hot carbonate of soda liquor—not boiling.
Steeped in oxychloride of calcium, 3°.
Soured as before, with hydrochloric acid.
Washed in water.

3. FINISHING.—Boiled in resinate of soda—resinous soap—half an hour.
Steeped while hot—not boiling—in the bleaching liquor.
Soured as before, with hydrochloric acid.
Washed in water.

By the double decomposition in contact with the object to be bleached, the bleaching is accelerated; and by changes of temperature, and the development of carbonic acid gas and chlorine—two most powerful bleaching agents—the decolorizing action is extremely effectual; in fact, no coloring matter can resist this bleaching process. By the double decomposition the chlorine enters into new combinations, forming bleaching liquids, which may be used again, and thus effecting no inconsiderable saving in chemical materials.

Mr. HIGGINS of Manchester has lately patented a method for bleaching cloth which possesses considerable merit.

About three thousand five hundred pounds of cloth, after being singed in the usual way, are passed through a solution, prepared by macerating about two hundred and twenty-four pounds of lime in a convenient quantity of water. When the cloth has been moistened uniformly with this liquid, a further dilution with water takes place, and two or three gallons of bleaching liquor of 8° Twaddle are poured in, and the whole boiled by steam for fourteen hours. After ebullition, it is withdrawn, washed in water, and steeped in dilute sulphuric acid of 3° T., or hydrochoric acid of 2° T.; again washed with water, and folded in another kier containing a mixture prepared in the following manner:—Into an iron or other vessel, put thirty gallons of water, one hundred and twenty pounds of soda ash, eighty pounds of American resin, or gum. Boil this compound by steam for eight hours, and then put in twenty-five pounds of lime, made into a cream with water. Boil for six hours more, and transfer to the kier, after which the cloth is folded in, sufficient water added, and the whole kept at ebullition for fourteen hours.

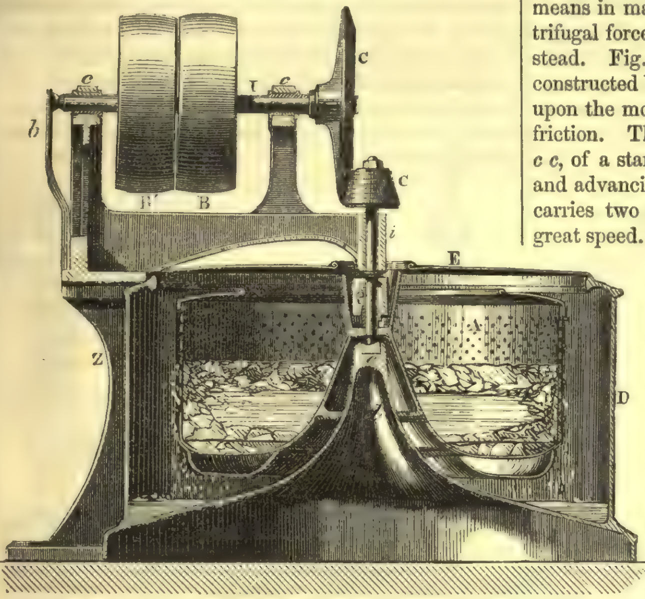
When the cloth is sufficiently boiled, it is removed and washed with water, then steeped in or passed through a bleaching solution, marking 5° on Twaddle. It is then passed through sulphuric acid 3° T., or hydrochloric of 2°, and afterwards well washed.

In some cases it may be well to give the goods another boiling in a kier with soda alone.

The following is the course followed for bleaching muslins, near Glasgow, as recounted by URE:—In fermenting muslins, they are surrounded by spent lies at a temperature of from 100° to 150° Fahr., according to the weather, and then allowed to ferment for thirty-six hours. In boiling one hundred and twelve pounds—

equal to one hundred and twelve pieces of a yard wide —six or seven pounds of pearl ashes, and two pounds of soft soap, with three hundred and sixty gallons of water are employed, and ebullition is maintained during six hours; the goods are then washed by the scouring machine; after which they are rebucked for three hours, with five pounds of pearl ash, and two pounds of soft soap; they are again washed, and afterwards immersed in a clear solution of bleaching powder of 6° on the indigo test tube, and allowed to remain in it for from six to twelve hours, when they are washed and steeped in dilute sulphuric acid, 3·5° Twaddle. The cloth is next well washed and boiled in two pounds and a half of pearl ashes, and two pounds of soft soap, for half an hour; again washed and immersed in a bleaching solution as before, at a strength of 3° on the indigo test, and allowed to remain in it for six hours. After this the fabric is again washed and soured in sulphuric acid of 3° T., or specific gravity 1·015. If the goods be strong, they will require another boiling, steeping, and souring. The sulphuric acid should be well washed out previous to the finishing operation with starch. Lime is occasionally taken for bucking muslins instead of alkali, the same proportion being used as above-mentioned for the latter; the time of boiling, however, is not prolonged beyond fifteen minutes, lest the fabric might be injured.

Fig. 190.



More recently, the plan adopted, by which the purest whites are produced for the London market, is as follows:—

Lime is seldom used for the finer muslins, as it is found to injure their texture, and the colors do not keep for any length of time. Caustic lies, made by boiling equal weights of caustic lime and carbonate of soda for an hour, allowing the solid bodies to deposit, and decanting off the clear liquor, are used for boiling the goods just as the potassa in the preceding methods; but in this instance no soap is used.

In finishing jaconets or muslins, after washing them from the sour, they are run through spring water containing a little fine smalt, which gives them a clear shade; if of a coarser quality, a little boiled starch is added to the water. From this they are wrung or pressed, and taken up by the selvage for the breadthing frame; they are then rolled upon a tin cylinder heated by steam, by which the piece is completely dried in fifteen minutes.

This method being considered a very ineffectual means in many instances, a machine known as the centrifugal force hydro-extractor has been introduced in its stead. Fig. 190 represents one of these machines, as constructed by Messrs. Rohlfs, Seyrig, and Company, upon the most improved plan. It is driven entirely by friction. The driving shaft, I, mounted in the cushions, *c c*, of a standard fixed to the frame of the apparatus, and advancing to the centre of the top of the drum, A, carries two pulleys, B, B′, which are made to turn with great speed. The drum, A, must revolve at the rate of from twelve hundred to fifteen hundred revolutions per minute. To the extremity of the driving shaft is riveted a conical disc, C, impelling directly by friction a conical pinion, C′, fixed on the vertical shaft which carries the drum, A. This pinion may be formed with leather, caoutchouc, or wooden washers, to prevent its being quickly worn, and also to avoid the noise which is commonly produced by rotation. That the pressure may be constant, a spring, *b*, is connected with the opposite extremity of the shaft, tending steadily to press the disc and the pinion against each other; a very smooth movement is thus obtained, with perfect regularity.

The body, D, of the machine is connected by the binder, Z, with the basis or support of the apparatus, and at the same time with an interior enlargement, *d*, which sustains the socket, *e*, and the lower extremity of the pivot. The drum, or copper, A, which is attached to this pivot, and contains the goods to be operated upon, moves therefore along with it, and keeps itself in equilibrium, for it is placed in the same conditions as a balance; that is to say, the rounded pivot, P, is not encased in its support, and may assume all the positions due to the inequalities of the load, being regulated by the force of rotation. The holes with which the drum is pierced, as shown in the figure, permit the water expressed from the goods by the powerful centrifugal action, to escape into the outer case in which the revolving drum is enclosed. The goods, when removed from this machine, are found almost perfectly dry.

When dried by either of these methods, the pieces are neatly folded and pressed; this finishes them for the market. From sixpence to ninepence per piece of twelve yards is obtained for the bleaching and finishing of this description of goods.

Book muslins, after being washed from the sour, are wrung or pressed, then hung up to dry in a room heated to 100° F., previous to being put into starch, prepared by boiling three pounds of it and twenty ounces of smalts in five gallons of water; the starch is wrought into the piece till clear, then removed to a cold room, and the selvages dressed or set before being put on the breadthing-frame in the heated stove, where the piece is stretched to its length, while three or four persons at each selvage keep it to the proper breadth. If a stiff finish is wanted, the operators keep exactly opposite each other.

Claussen's process is employed with success in muslin bleaching.

In the foregoing pages, the process for bleaching calico or cotton fabric has been explained; but unless the article must pass at once to the hands of the printer, it requires to undergo certain finishing operations, which render it more marketable, and in every respect improve its appearance. The pieces of cloth, after they are washed, are passed between the squeezing rollers, to remove the greater part of the imbibed water. Every precaution already noticed, when speaking of this department, is carefully observed, so that the action of the rollers is not deranged or impeded by knots, *et cetera.*

After drying by one of the preceding methods, the crumpled piece is pulled out to its full breadth. This portion of the work is usually performed by females, and is termed *thumbing;* it is not successful, however, in extending the selvage evenly, and in order to make the parts folded in straight, the operator knocks them against a smooth beating stock, first on one edge and then on another. By this means the pieces of cloth are opened to their full breadth, and all the folds and creases removed. If only convenient lengths were connected endways hitherto, now *all* the pieces on hand are stitched together, end to end, by means of a stout packing needle and thread, to prepare them for the next operation.

Fig. 191.

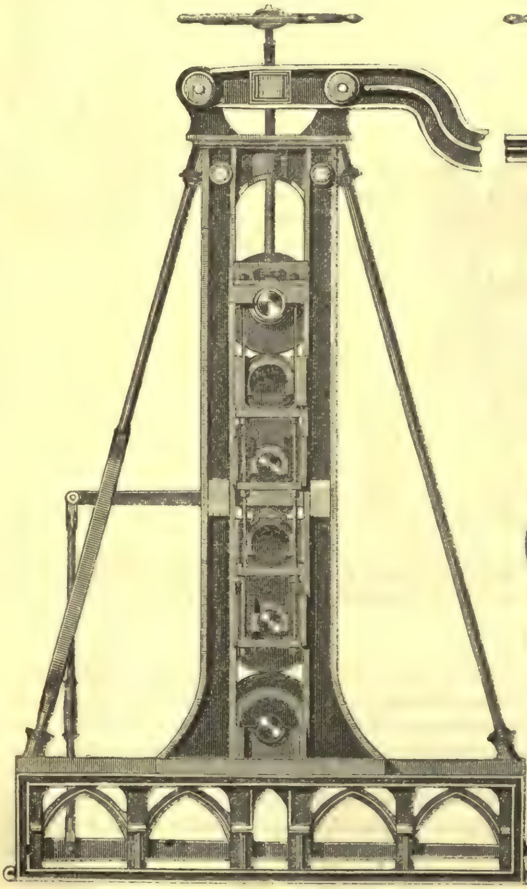
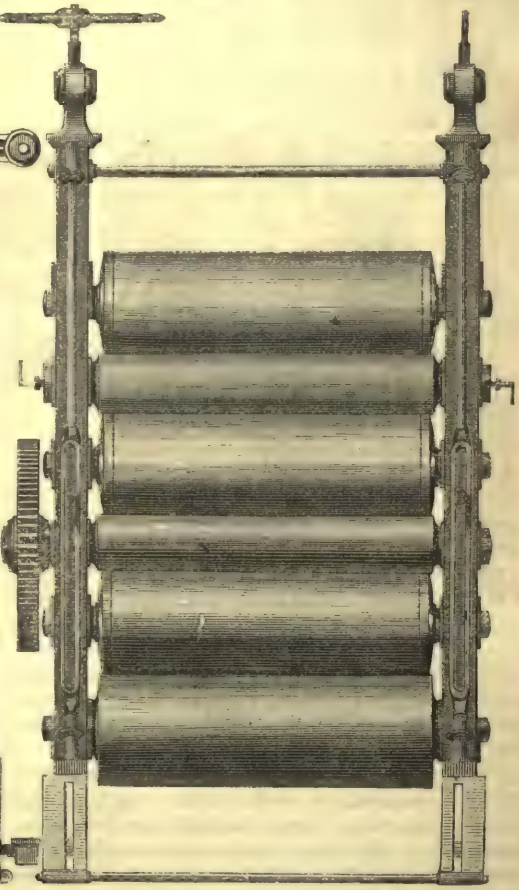


Fig. 192.



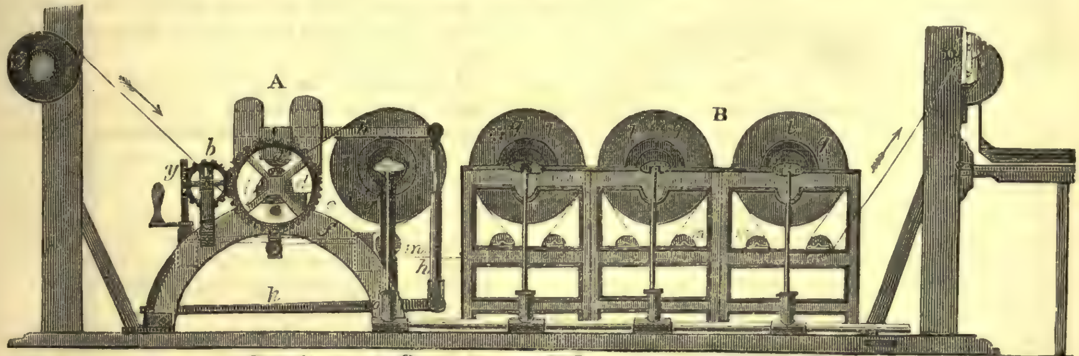
14. The mangling or pressing of the cloth while still wet, between rollers, forced together by levers to which considerable weight is attached, serves to equalize any moisture which may be retained; it also flattens excrescences which might be found in the threads, stretches the piece smoothly and evenly round the roller, and renders it fit for receiving the starch.

Figs. 191, 192, represent an end and front elevation of a water mangle of the most approved construction, by **More and Son**, Glasgow. It consists of six rollers, three cotton and three brass, fixed upon a stout cast-iron frame; the lowest roller is brass, the next cotton, and so on, alternately. The pressure is applied to the rollers by a large lever on the top of the frame, and there is also a separate arrangement of levers for the three under rollers, whereby a greater amount of pressure may be obtained if required.

15. Starching was, no doubt, originally resorted to with the fraudulent intent of making the purchaser believe that the cloth was much stouter and thicker than it really was, and custom still allows it, although it is universally known that this preparation has been used. The process of starching is of little interest to the scientific reader, but, as a part of the bleacher's business, it will be well to describe the practice. Prepared starches, as used for the work of the laundress, would be too expensive for this purpose, and on this account they are never taken. Flour is the substance usually employed; but it is necessary, first, either to remove the gluten or destroy its cohesion, so that it may not form clots upon the cloth. For this purpose the flour and water are mixed in the proportion of one pound of the former to a gallon of the latter; this mixture is allowed to rest for twenty-four hours, during which a brisk fermentation takes place, lactic acid being formed by the decomposition of the gluten, and the water acquiring a specific gravity of 1·015. The menstruum is then strained through a fine hair or wire sieve, whereon the husk is retained, the starch granules passing on with the liquid; after this it is diluted with water according as a thin or stiff paste is required, impregnated with a little indigo to heighten its color, and then boiled into a paste.

In some cases the starch is mixed with such substances as fine porcelain clay, and calcined sulphate of lime finely ground, in equal proportions. This mixture is laid on one side of the cloth, but by the force of pressure exerted by the rollers the body of the texture is impregnated with it, and when dry it appears to have gained considerable solidity and strength. The purchaser is, however, so well acquainted with the circumstance, that he is seldom deceived by the sophistication.

Fig. 193.



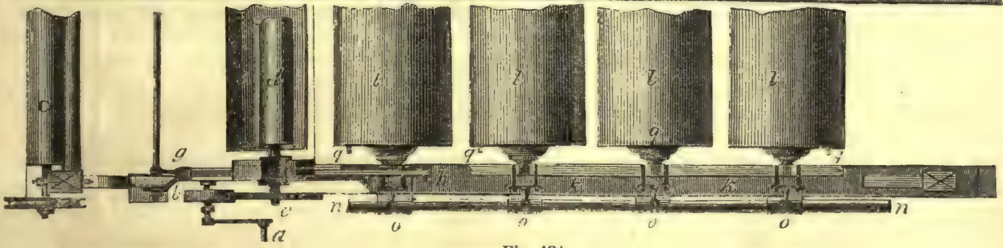


Fig. 194.

The starch is sometimes laid upon the cloth by a calender composed of three or four rollers, pressed together by means of levers moving in grooves in the framework. The trough containing the stiffening is situated at the base, and in it is placed a roller; the cloth, before passing between the superior rollers, has to come under this one, and thus it gets filled with the starch, the excess of which is removed during its passage over the other rollers. After this the cloth is hung upon rails in a chamber, heated by the flue from an adjoining furnace, which passes round the walls, and returns in the middle of the apartment to the chimney. Thin brickwork or plates of cast-iron usually shield these flues from the cloth. On first hanging up the fabric the temperature is low, but is gradually elevated to 110° Fahr. as the moisture is expelled. This method is laborious and oppressive—the workmen during the spreading on the rails being almost denuded. Mechanical agency has been made to supply both the starching and drying simultaneously, thus superseding the trouble attendant upon the manual process.

Figs. 193 and 194 represent the machine employed for this purpose: the first is a side elevation, and the other a plan. In these figures the same letters indicate the same parts. A is the box containing the paste, which is used to starch or stiffen the goods; *a* is a winch, which can be employed to turn the machine by the hand, although in large factories it is usually impelled by steam power; *b* is the driving pinion; *d d′*, two brass rollers with iron shafts, the lower of which is moved by the wheel, *c*, in gear with the pinion, *b*. The uppermost roller, *d′*, is turned by its friction with the other, which is pressed upon it by the weighted lever, *h*; *e* is the trough filled with the paste; it rests upon the bars, *f*, and may be placed higher or lower by means of the adjusting screws, *g*, according as the roller, *d*, is to be plunged more or less deeply. A brass roller, *i*, serves to press down the cloth into the paste.

The drying portion of the machine is denoted by B. In this department, *k k* is the iron framing which supports the five drums, *l l l*, *et cetera;* these drums are hollow copper cylinders heated by steam; *m m m*, *et cetera*, are small copper drums in pairs, turning freely on shafts under the former, for stretching and airing the goods during their passage through the machine; *n n* is the main steam pipe, from which small copper tubes, *o o*, branch off into the superior drums. There is a similar main pipe and branch communications at the other end of the drums for discharging the condensed water, the pipes passing through air-tight stuffing-boxes. Whenever the steam becomes feeble, or it is necessary to turn it off, there are valves, *q q*, in the drying drums, which open internally to admit air, so as to prevent the collapsing of the cylinders, which the pressure of the atmosphere would occasion when they are exhausted; C is the cloth-beam from which the starching roller draws forward the goods; D are two rollers, of which the lower is provided with a band pulley or rigger, driven by a similar pulley fixed upon the shaft of the starching roller, *d*. These two rollers pull the goods through the drying machine, and then let them fall either upon a table or floor, as best answers. In this operation the cloth is either completely dried, or left slightly damp, according to the wish of the operator; the former by communicating high-pressure steam to the drying drums; the latter by expediting the passage of the cloth, and introducing steam of a lower temperature.

16. The operation succeeding the starching and drying is the calendering and finishing.

This is done by passing the cloth first over a sprinkling or damping machine, consisting of a circular brush, the tips of the hairs of which touch the surface of the water in a tank underneath; and by communicating a rapid motion to this brush, it discharges a shower of minute drops upon the piece as it is drawn from one end of the machine to the other. At first the moistening is partial; but after the cloth is permitted to remain in a heap for some hours, the dry parts absorb the excess of water from the wet spots, and the whole acquires a uniform dampness. The damp cloth is laid down in front of the calender, which consists of a number of rollers running in a stout cast-iron frame, and pressed together by weighted levers; the rollers are fixed parallel one over another, and bear a wheel gearing on their shafts to make them revolve. The smallest two of these rollers are of cast-iron, well turned and polished, and the large ones are made of paper. The cloth is made to pass between the rollers, till it finally makes its exit at the back, and is received upon a cylinder, technically called the *batching* roller. During the passage of the cloth over the rollers, its appearance is considerably changed. When it is simply passed between the rollers, the threads are only flattened, but by the further process a peculiar softness is given to it; on the contrary, if two folds of the cloth are conveyed through at the same time, the threads of one fold make an impression upon the other, and both appear hard and wiry, with alternate indentations between the threads. By varying the number of folds, the wiry appearance which the goods present after this treatment, is altered in a corresponding degree.

When the cloth has undergone all these operations, it is folded up, stamped with the peculiar brand corresponding to the standard of the market at which it is to be disposed of, and is ready to be sent to its destination. Should the calico be intended for printing at home, the latter process of calendering is not applied, and sometimes the starching is dispensed with, as it is only required in this case to have the natural color of the fibre of the cloth removed. It is customary, however, to stiffen the goods, as this affords certain facilities in printing them. After the starching, the cloth is folded upon a roller; next beaten against the stone used for the purpose of taking away any creases, and also to make the selvages straight; then dried; and, lastly, folded up in small bales of fifteen or twenty pieces each.

Such is a detailed account of bleaching, with special reference to cotton thread; but as this forms only one of the class of fibres from which cloth is made, and all of them differ in their constitution, the nature of each must be explained, and the modification of the preceding operations which is found to be best adapted for bleaching the respective materials. Of the vegetal fibres, flax is most extensively used next to cotton, and therefore the reader's attention will now be directed to the bleaching of linen goods.

BLEACHING LINEN.—Before entering on the method of conducting this process, a short allusion to the nature of the material from which the cloth is manufactured, will contribute to a clearer knowledge of the operations to which the goods are subjected. Linen stuffs are manufactured from the fibre of the flax plant—see Fig. 195—some account of which has already been given at page 301. This fibre is quite dissimilar to cotton, not only in its nature—as shown in the microscopic view of the flax fibre, indicated by B, C, in Fig. 175—but in the quantity and quality of the coloring matter which it contains. It has been shown that cotton loses only about five per cent. by bleaching, but flax parts with fully one-third of its weight. This large quantity of coloring matter is not indigenous to the fibre, which, in its natural state, has only a light grey, yellow, or blond color; but the plant acquires it during the preliminary process of steeping, or retting, as has been shown by several scientific men, and especially by Mr. LEE. This gentleman conceived the idea of discontinuing the steeping or retting system, and procuring the fibre in its natural state, by which he could dispense with the tedious system of bleaching then practised; he, accordingly, took out a highly privileged patent in 1812, for a machine for crushing the flax, and removing the woody matter, but from some mishap, arising either from defect or prejudice, it did not succeed. Another patent by Messrs. HILL and BUNDY followed, but this met with the same fate, and both were discontinued.

The retting of the flax—of which there were three systems, namely, dew, pond, and river retting—was the evil proposed to be avoided by these patents; had they been successful, there is no doubt but that the linen trade would have derived an almost incalculable benefit, inasmuch as the fibre could be produced in larger quantity, and possessing greater strength than when subjected to the action of water, besides being devoid of the excess of coloring matter. The flax plant consists principally of two parts: the wooden centre, known by the term *shove* or *boon*, and the external fibrous portion, which, when separated from the former, constitutes the flax—both being agglutinated by a kind of cement or gum. It was with the view of removing this blending substance that the flax was submitted to one or other of the various steeping processes above mentioned. The dew retting was performed by exposing the stalks to the action of air and moisture, till the gummy matter had fully undergone a fermentative action, which decomposed it, and thus disunited the shove and fibre. Considerable time was required to complete this part of the work; and not unfrequently was the flax entirely spoiled, owing to the unfavorableness of the season, so that the computation of the value of the crop whilst it was green, or on the point of gathering, was accounted, in a trite proverbial saying, equivalent to *counting the chickens before they were hatched.* The next method of steeping it in ponds and rivers was not more encouraging, in obviating injury to the fibre, but the time required to complete the fermentation of the gummy substance was much shorter. It is well known, however, that, during the retting, certain poisonous bodies are given off, which affect the water so as to destroy life in fishes, and the air is also greatly vitiated by the exhalations from it; in countries, therefore, where flax is grown extensively, this retting process has been prohibited by direct statutes. Latterly, through the exertions of the Royal Agricultural Flax Society of Ireland, much has been done to bring the culture and manufacture of flax into a more healthy and lucrative state, both to the farmer and manufacturer. Various improvements have been suggested and patented at different times since those of LEE and HILL above-mentioned, but the best is that by which the retting or fermentation is executed in from seventy to ninety hours. This is performed by steeping the flax straw in water heated to between 70° and 90° Fahr., a range of temperature which is most conducive to the fermentation and rupture of the gummy mass. That tepid water was highly favorable for retting, was a fact long known and actually carried out by those whose custom it was to manufacture their own linen, though not in so convenient a form as that specified in the above patent; for such flax as would be thoroughly retted in ten days in hot July weather, would require double the time at the end of August or the beginning of September. Still, the above application is productive of great advantages, in preventing the destructive influence of the prolonged fermentation and putrefaction consequent upon the old system of steeping; besides this, the compound of the coloring matter and the fibre is not so copious or permanent as when the old process is followed.

Fig. 195.

Chevalier CLAUSSEN'S patent process consists in the partial cleaning of the flax straw in the raw state, for the purpose of reducing the bulk, and facilitating the transport, as also to obtain shoves suitable for cattle food. Flax thus roughly cleaned, may now be treated with steam or hot water, or, as he prefers, boiled for two or three hours in a solution of caustic soda, and then steeped—

1st. In a solution of sulphate of magnesia.

2d. In carbonate of soda.

3d. In water acidulated with sulphuric acid—then washed.

Goods manufactured from hemp or flax, prepared by this process, lose only one half per cent. in bleaching, instead of 33 per cent. as common steeped flax does, while the yarns and cloths obtained are of a much finer quality, and much easier spun and woven.

The coloring matter is quite insoluble in boiling water, acids, and alkalies; but the latter, or their carbonates, take it up, especially after it has been exposed to oxidation, whereby the excess of the hydrogen is removed. Hemp is analogous to flax in this respect, for the decoloration of both depends upon the oxidation and the removal of the acidified coloring matter by means of an alkali. Exposure to the air was for a long time, and in some parts still continues to be, the only means resorted to for removing the color, notwithstanding the known efficacy of bleaching powder.

Although oxychloride of calcium will execute in a few minutes what the old system performed by weeks of exposure to air, light, and moisture, yet it does not penetrate the fibre completely during the short time of its immersion; and, therefore, it requires many chemickings and buckings before the linen cloth or fibre is bleached. This continued boiling, *et cetera*, is that which renders the bleaching of linen goods so very difficult.

The custom for a long time was, to submit the cloth to several buckings, and exposure upon the grass for six or eight days after each boiling, before the souring or bleaching powder was applied.

Mr GRIMSHAW, near Belfast, introduced the souring of the goods at an early stage, by which the execution of the work was greatly facilitated. Still the bleaching of linen goods is a very tedious process whatever plan be adopted, requiring from eight to eighteen separate buckings, chemickings, and sourings, with a repeated scouring or steeping after each operation, and having to lie upon the grass from thirty to sixty days. If the time of exposure be shortened, then the buckings and other operations must be multiplied, to make up for the diminished effects of the air upon the cloth.

In the linen bleach-works, the operations are, so far as the steeping, bucking, souring, chemicking, and washing are concerned, similar to those described in bleaching cotton; it is, therefore, unnecessary to enlarge upon them—it will be sufficient to mention the several operations.

The following are the three systems pursued in bleaching linens, especially amongst the Irish, the quantity of cloth being three hundred and sixty pieces of thirty-five yards each.

First Plan, in which there is no exposure upon the grass:—

1st. The cloth is steeped in a weak alkaline lie, and fermented thirty-six hours; then washed.

2d. Bucked in a lie of sixty pounds of caustic soda, dissolved in about nine hundred gallons of water for six hours; washed.

3d. Steeped in a solution of oxychloride of calcium, the strength of which is regulated by the quality of the cloth, and its high state of coloration; the time allowed is about fifteen hours, after which it is washed.

4th. Soured in a solution of sulphuric or hydrochloric acid, 3·5° Twaddle, for six hours, and scoured.

5th. Bucked in a lie of caustic soda as above, for four hours, then scoured.

6th. Chemicked in a solution of oxychloride of calcium, as before, during fourteen hours; washed.

7th. Steeped in a solution of sulphuric acid for ten hours, and washed.

Lastly, Treated with brown or black soap upon a rubbing board, and washed.

Second Plan; exposed on grass:—

1st. Steeped in weak alkaline lie, and fermented thirty-six hours; then washed.

2d. Boiled with sixty pounds of pearl ashes—crude carbonate of potassa—and washed; then exposed on the grass during three or four days.

3d. Bucked in a lie of eighty pounds of pearl ashes; washed, and exposed on grass as before.

4th. Bucked in a lie of ninety pounds of pot ashes—purified carbonate of potassa—washed, *et cetera.*

5th. Bucked in a lie of eighty pounds of pot ashes; washed, *et cetera.*

6th. Bucked in a lie of sixty pounds of pearl ashes; washed, *et cetera.*

7th. Soured in dilute sulphuric acid and washed.

8th. Boiled with sixty pounds of pearl ash; washed, and exposed on the grass.

9th. Steeped in oxychloride of calcium solution, and washed.

10th. Soured in dilute sulphuric acid; washed, and exposed on the grass.

11th. Boiled with thirty pounds of pearl ashes; washed, and exposed on the grass.

12th. Boiled with twenty pounds of pearl ashes; washed, and exposed on the grass.

13th. Soured in dilute sulphuric acid; washed, and exposed on the grass.

14th. Soaped as above, on rubbing board; washed.

Third Plan; exposed on the grass:—

1st. Steeped in weak alkaline lie, and fermented thirty-six hours; washed.

2d. Boiled with sixty pounds of lime; washed.

3d. Boiled with fifty pounds of lime; washed.

4th. Soured in sulphuric acid, one and a quarter gallon to three hundred gallons of water; washed.

5th. Boiled with sixty pounds of soda; washed; exposed on the grass for three or four days.

6th, 7th, 8th, 9th, 10th. Boiled with sixty pounds of soda; washed; exposed on the grass for three or four days.

11th. Soured in sulphuric acid; one gallon to three hundred of water; washed.

12th. Boiled with fifty pounds of soda; washed.

13th. Steeped in oxychloride of calcium solution of 1¼° strength on indigo test tube; washed.

14th. Boiled with fifty pounds of soda; washed; exposed on grass.

15th. Boiled with fifty pounds of soda; washed; exposed on grass.

16th. Steeped in oxychloride of calcium solution, 2° strength by indigo test tube; washed.

17th. Boiled with fifty pounds of soda and washed.

18th. Steeped in oxychloride of calcium solution, 6° on indigo test tube; washed.

19th. Soured in sulphuric acid, one gallon to three hundred of water; washed.

20th. Scoured with brown soap; washed in pure water.

The following is Chevalier CLAUSSEN's process for bleaching linen and linen yarns:—

A. SCOURING.—1st. Boiled for two or more hours in a solution of caustic soda, 1° to 2° Twaddle.

2d. Steeped in a solution of sulphate of magnesia, 4° Twaddle.

3d. Steeped in a solution of carbonate of soda.

4th. Soured with sulphuric acid, 2° Twaddle.

5th. Washed.

B. BLEACHING—

1st. Steeped in hot carbonate of soda.

2d. Steeped in hypochlorite of magnesia.

3d. Steeped in carbonate of soda.

4th. Soured with sulphuric acid.

5th. Washed.

C. FINISHING.—To produce pearl white—

1st. Boiled half an hour in a solution of resinous soap.

2d. Steeped, when not too hot, in a solution of hypochlorite of magnesia, 2° Twaddle.

3d. Soured with sulphuric acid.

4th. Washed.

Before concluding this part of the subject, it may not be improper to mention a continuous system of bleaching, patented by M. BOUCHARD in France, which promises to be highly efficient. By this method the creases into which the cloth is thrown in the ordinary kier, by reason of the pressure it is subjected to during the boiling, are avoided; it is likewise continuous, and therefore calculated to perform more work than could be executed in the ordinary way.

In BOUCHARD'S process, the pieces attached to one another endwise are taken up by rollers on a double metallic casing, which communicates a certain degree of heat to the goods; from this the cloth passes into a steam-bath, and emerging from the latter, it passes round the opposite corresponding part of the double metallic casing, and is then smoothed in its course over different rollers. It is dried and dressed by its passage over a great part of the surface of a drum or cylinder of large diameter, which follows the preceding series of rollers; this large double-cased cylinder or drum, is heated by a current of steam. The cloth, by embracing its circumference, receives a regular drying and dressing; and these operations are completely finished by the passage of the goods over other rollers, and between a pair of squeezing cylinders. After undergoing this pressure, which is the last operation in the process of scouring, the cloth is deposited on a stretching table, as at first, on which it is folded and put up.

Fig. 196 is a longitudinal section of the machine employed; it measures about six feet in width, to adapt it to cloth of all sizes.

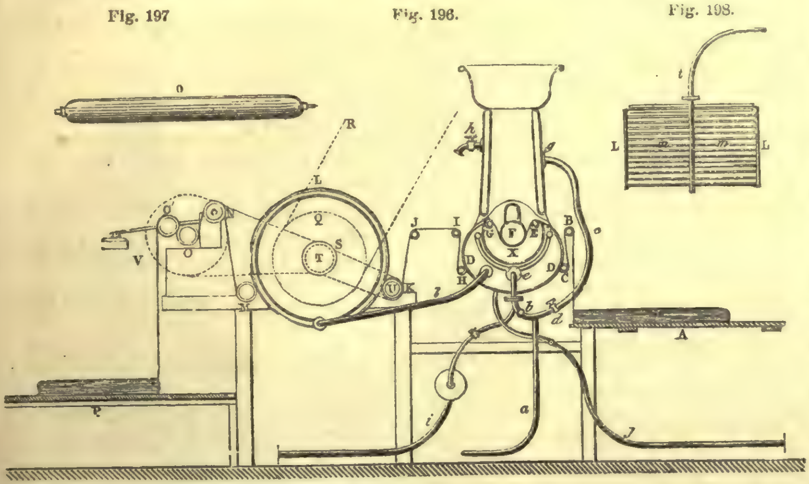


Fig. 197 Fig. 196. Fig. 198.

The goods in one long web lie on the table, A, placed on the right of the machine. In the first place, the cloth passes round the roller, B, then descends round the inferior roller, C, and rises again bearing on the outer surface of the double-cased reservoir, D. The goods then continue their progress, passing round the roller, E, and the cylinder, F, from which they ascend to the roller, G, and again, in descending, bear on the opposite corresponding surface of the double-cased vessel, D. Leaving this, the cloth is conducted round the roller, H, and then round the rollers, I J K; thence it proceeds round the large double-cased drum, L, and then from the larger roller, M, it rises to the upper roller, N, and finally passes between the squeezing rollers, O O′, from which it is again laid down on a stretching table, P, at the end of its course.

In this mechanical contrivance, the continual taking up of the cloth results from the transmission of the movements in the following manner:—Q is a pulley, which by the strap, R, receives motion from the prime mover. From the axis of this pulley the motion is communicated to the roller, K, and to the squeezing cylinder, O, by means of the pulleys, S T U V. Thus the continual taking up of the cloth is effected by the roller, K—and when necessary, by the roller, M—and by the aforesaid squeezing-roller, O; the pressure of the upper roller, O′, on the inferior one, is regulated by a weighted lever. One of these squeezing rollers is represented in Fig. 197.

The admission of the steam into the double-cased vessel, D, is effected by the pipe, *a*, which communicates with the boiler. This pipe is connected with two branches, *b* and *c*, the former being fitted with a stopcock, which serves to allow the steam to enter the cylinder, *e*, at pleasure; this cylinder is perforated over a part of its lower circular surface, and in its whole length, with small holes, so as to force the steam from the cylinder to pass within the double casing by these holes. The steam thus introduced into the vessel, D, first heats the outer case, then penetrates into the interior, X, in which are placed the hollow metal rollers, E F G. This concavity is a steam-bath, to which the steam passes by small holes perforated at its base; it is here that the goods are submitted to the penetrating action of the steam. From this basin, which occupies the whole extent of the reservoir, D, the steam issues into the iron double-cased chimney, *g*, to escape upward.

The steam likewise arrives into the casing, *g*, by the branch, *c*, which is also furnished with a stopcock, *d;* and it maintains the elevated temperature of the chimney, which is fitted with another stopcock, *h*, required for working the apparatus. On the side opposite to that at which the steam enters, it issues out by the return pipes, *i* and *j*, to be again conveyed in any direction.

The large double-cased drum, L, is supplied with steam by the branch, *l*. This drum consists of an outer casing of copper and an inner cylinder of cast-iron; it is furrowed with circular grooves or channels, *m*, over its whole length, as represented in the horizontal section, Fig. 198; there is likewise a longitudinal canal, which communicates with all the circular channels. By this arrangement the steam circulates very equally within the double casing, so as to diffuse the heat perfectly over the whole circumference, and throughout the entire extent of the surface. The steam escapes by the pipe, *t*, from the side opposite to that by which it entered.

BLEACHING OF OTHER VEGETAL FIBRES WHICH ENTER INTO THE FORMATION OF TEXTILE FABRICS.—Various other substances enter into the formation of cloth besides those already noticed, the principal of which are China grass—*Urtica nivea*—and jute—*corchorus capsularis*—both of which are imported from the East Indies. These substances are of recent date in the annals of English manufacture, but their importation has considerably increased during the last few years. Of the former, three hundred and twenty bales, and twelve thousand two hundred and sixteen tons, entered the port of Liverpool alone in 1850. This is one evidence of the growing activity of our manufactures; and the samples exhibited at the Great Exhibition of 1851, fully bore testimony to their adaptation to the wants of the community in the fabrication of cloth.

The removal of the fibre and bleaching of these substances are nearly the same processes as those just described. Messrs. WRIGHT and COMPANY took out a patent for the preparation of China grass in 1849. The merits of the process lay in the steeping of the crude material in cold water for twenty-four hours, and for an equal period in water heated to 90°, the stems being then boiled in alkaline lies. The fibre is next thoroughly washed with pure water, and finally subjected to the action of a current of steam till nearly dry. The usual methods of bleaching cotton and linen are applicable also in this instance.

Chevalier CLAUSSEN's patent process bleaches not only tow and refuse from flax mills, but also jute, China grass, phormium, Manilla hemp, and many other fibres, for the purpose of converting them into substances suitable to be spun, and mixed with cotton, wool, or silk, at CLAUSSEN's Patent Company's Works, Leeds, as also in France, Holland, Belgium, and the United States.

BLEACHING OF WOOL AND SILK.—It was stated at the beginning of this article, that the textile fibres which formed cloth were divided into two classes, vegetal and animal. The means resorted to for decolorizing the former having been treated of, it will now be necessary to direct attention to the systems followed for bleaching the latter. Wool and silk are the only animal fibres which enter into the formation of cloth, and their value in this respect is much greater than that of the substances already described. As wool and silk are quite different from each other in nature and qualities, it will be necessary to speak of them separately.

Cleansing and Bleaching of Wool.—Wool is unlike the fibre of cotton or flax, inasmuch as it is composed of very fine filaments or tubes, the external surface of which presents the appearance of transverse corrugations, which under the microscope appear to be covered with a line of circular apertures leading to the interior part of the cylindrical filatures. It is naturally covered with a greasy matter called the *yolk*, derived chiefly from cutaneous perspiration, but also secreted in part by the pores of the wool itself; it possesses a peculiar odor, well known to all who frequently come in contact with sheep. This varnish is highly prejudicial to the article in a manufacturing point of view, and to remove this deteriorating body is one most important part of the bleacher's business. To accomplish this more effectually, it is necessary that he should be acquainted with its nature and composition; and to furnish him with this information, the annexed particulars of the researches of VAUQUELIN are transcribed:—

According to this philosopher, the unctuous matters consist of a kind of soap soluble in water, a small quantity of a waxy matter, an odorous substance, potassa salts—principally acetate and carbonate of the alkali and chloride of potassium—together with a small portion of lime. Although these salts, and also the saponaceous compound, are soluble in water, and, consequently, may be removed by continued washings in that liquid, yet this is not the practice in bleaching establishments: firstly, because it is slower, and secondly, because it is found that there remains a certain portion of it which dims the silky lustre possessed by the fully purified fibre. The methods followed are, like those for bleaching cotton and linen goods, various in their details, but the same in principle; and, like the foregoing, the operation may be divided into two principal divisions, the scouring and decoloration. A moment's consideration will suffice to show, that in these respective departments, especially the scouring, the treatment of woollen goods must be varied from that of cotton or linen; for the repeated buckings with alkaline lies to which the latter are subjected, would completely destroy the filaments of the wool, and the use of caustic lime would likewise put an end to its capability of receiving colors; hence these methods must either be renounced altogether, or so modified that their pernicious influence upon the goods will be prevented.

The usual method of scouring, which has been for a considerable period, and still continues to be, practised for bleaching wool, is to steep it for some time in a bath formed of about five parts of soft water and one of stale urine, boiled together for some time, and then allowed to cool to about 70° or 90° Fahr. When the wool is completely saturated with this solution, it is well stirred for about twenty minutes; it is then thrown upon a croft or drainer, placed over the vessel in which it was steeped, so that all the liquor returns. After being thoroughly drained, the wool is taken and exposed to a current of clean water, and kept continually stirred till no more impurities are extracted. Whilst the final rinsings are being made, a fresh quantity of wool may be exposed to the action of the lie, but it is necessary to renew its activity from time to time by adding fresh liquor to it. The solution should not be thrown away after each operation, as its detergent qualities are somewhat improved by the soapy matters extracted from the wool; but at length the accumulation of this matter renders it so foul, that it must be entirely cast away and a fresh quantity made. Industry does not allow even this putrid liquor to be lost, but, by ingenious and scientific manipulations, prepares from it various highly useful products. In the preceding method, the active detergent is the carbonate of ammonia which is present in the urine, being derived from the decomposition of the urea. It exerts its influence by forming an ammoniacal soap with the fatty or greasy and resinous matter in the wool, which dissolves in and is carried off by the water. When the material is converted into a fabric, this process is seldom adopted, perhaps on account of its offensive odor. Crystallized carbonate of soda is substituted, but this is sometimes found insufficient to completely eradicate the impurities, and soap is used as an auxiliary; this, from its known property of partly decomposing, in aqueous solutions, the fatty acid uniting with the impurities of the cloth, and forming a compound easily assimilated by the alkaline body in the lie and dissolved in the water, rapidly brings about its purification, whereas neither the water alone nor the carbonate of soda could effect it.

One thing must be particularly guarded against in scouring woollen goods, namely, the application of an elevated temperature; for although the resinous and greasy matter in the texture is best saponified in the heat, yet its use in this case would cause serious injury, as well to the filaments by decomposing them, as by causing the piece to contract and felt more or less, according to the degree and duration of the heat. The heat most favorable to the scouring of woollen goods is 60° to 65° Fahr. This great difference in the principle of bleaching woollen and cotton or linen goods, necessitates as great a dissimilarity in the mechanical apparatus employed. It is necessary to keep woollens stretched during the time they are passing through the scouring liquor, otherwise they will contract unequally, and this shrinking will of course disfigure their beauty and finish.

The annexed cut, Fig. 199, represents the machine employed for this purpose.

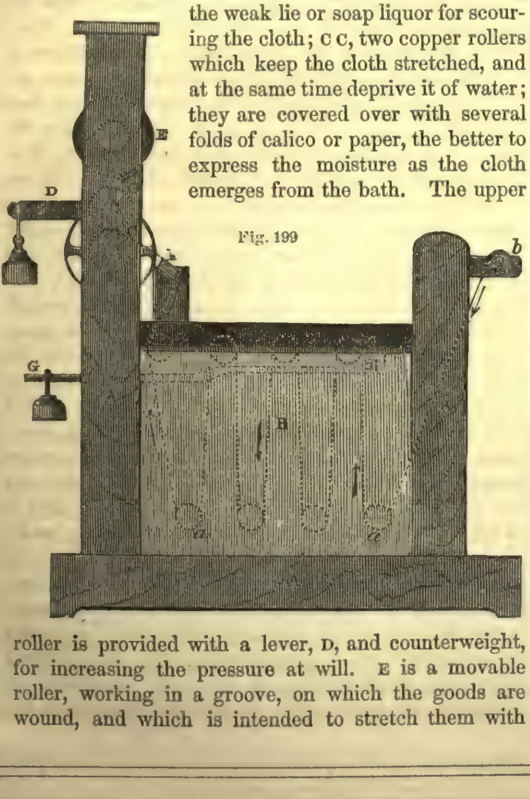


Fig. 199

A A is a wooden framework; B, a vessel containing the weak lie or soap liquor for scouring the cloth; C C, two copper rollers which keep the cloth stretched, and at the same time deprive it of water; they are covered over with several folds of calico or paper, the better to express the moisture as the cloth emerges from the bath. The upper roller is provided with a lever, D, and counterweight, for increasing the pressure at will. E is a movable roller, working in a groove, on which the goods are wound, and which is intended to stretch them with greater or less force, according as the weight at the extremity of the lever, F, which is in contact with it, is made to act. G is a widening guide, with diverging grooves, to stretch the fabric before it arrives at the rollers, and prevent folding or overlapping. *a a a a* are small wooden cylinders, resting upon copper cushions; by these the goods are made to circulate in the lie for a certain time.

After the cloth is sufficiently impregnated with the lie, it is passed round the cylinders, *a a a a*, and fixed—four, six, or more pieces, according to their length—over the cushion at the point *b*. The working of the machine is carried on, by putting one end of the web of cloth in communication with the traction rollers, C C, the remainder being passed into the vessel filled with warm water, and after circulating there for a certain time, coming to the squeezing rollers, C C, where it is divested of most part of the liquid, and then folded upon the roller, E. After this the cloth is removed, to undergo either a new lixiviation or washing. When it is necessary that the last traces of the impurities of the filaments should be removed, the goods must be repeatedly transmitted through the carbonate of soda lie, alternated with an immersion in a bath formed of carbonate of soda and soap.

Chevalier CLAUSSEN, in cleansing and bleaching of wool without the application of heat, uses a feeble solution of caustic soda, in which he washes the wool, and when the fatty matter from the wool has formed a soapy liquid, he gradually and cautiously adds small quantities of caustic soda, so as always to preserve a small excess of causticity. After this, the wool is well soaked with a solution of carbonate of soda, put into a weak solution of sulphuric acid, and then washed. For very fine qualities of wool, carbonate of ammonia may be used instead of carbonate of soda.

For bleaching, he steeps the wool in carbonate of soda, and exposes it while wet to the fumes of sulphur, or puts it into a solution of sulphurous acid in water.

In pursuing the ordinary process, when the scouring is thoroughly performed, and all matters, as well of the lies as those inherent in the cloth, are separated by washing in clean water, the second division is entered upon; namely, the

Bleaching.—In decolorizing woollen fabrics, oxychloride of calcium or bleaching powder is never used, sulphurous acid being in this case more eligible. This gaseous body, instead of transforming the coloring matters into other products more or less colored, which are no longer retained by the fabric, unites with the colored substance, and forms a very permanent colorless compound which remains adhering to the fibre. A great many bodies having decolorizing power behave thus with colored substances, particularly chlorine, sulphide of hydrogen, and the like; but as they do not always constitute definite compounds, it is difficult to give the true rationale of the change. Bleaching by means of sulphurous acid is of a rather ancient origin, and, in consequence of the facility with which it could be performed, was very extensively practised. It is technically termed *sulphuring*.

The modern way of applying this acid to the elimination of colors, is either in the gaseous state, or by a solution of the gas in water. When employed in the gaseous state, a large chamber is provided, the door of which closes hermetically; this chamber is furnished with valves and openings for supplying the air, as well as for the admission of the ignited sulphur; there is also a series of strong upright planks fixed in couples at proper distances from each other, and studded with pegs, the extremities of which are enlarged, and have a notch near the end, in order to prevent the cloth which may be strung upon them from falling off. All the pieces of cloth being stitched together so as to form one length, it is passed round these pegs, being carried alternately from one to the other in a horizontal course. When the cloth is fixed upon all the pegs of the frame, the chamber is hermetically sealed, and the burning sulphur introduced at the openings at the base; these are immediately closed, and the combustion of the sulphur is carried on merely by means of the air contained in the chamber. When this is exhausted, the burning of the sulphur ceases, but the interior of the chamber is charged with sulphurous acid gas, which is taken up by the moisture of the cloth; and, being thus brought in contact with the coloring matter, as it insinuates itself into the pores of the fabric, it exerts its bleaching powers very effectually. It requires about twenty-four hours' contact with the cloth before all the color is destroyed, and sometimes the air has to be renewed, and a fresh quantity of sulphur burned, before the work is completed.

The next method by which woollens may be bleached, is by employing the sulphurous acid in a state of solution in water. Bleachers, it appears, have not hitherto practised this method to any great extent, although it is very apparent that its influence upon the cloth must be more regular and economical than when the gas is applied in the state of vapor. O'REILLY was the first to call attention to this system of bleaching, and his experiments went to show that an immersion of four hours in a bath of water saturated with this acid, would be sufficient to yield a purer white than could possibly be obtained by the other course.

The gas is easily and economically prepared by heating sulphate of iron and sulphur to low redness in a close cylindrical vessel of earthenware; an exit pipe at the end of the cylinder would convey the gas to a vessel adjoining, which may be filled with moss or some porous matter that will not absorb the gas, but clear it from any impurities which may be carried off mechanically; thence the gas could be conducted to the water cistern where it is to be absorbed, and admitted into it till the solution is saturated. To insure the complete impregnation of the water, the gas, as it makes its exit from the cistern filled with moss, *et cetera*, above mentioned, could be admitted at the base of a tower of convenient height filled with small stones, pieces of earthenware, and the like, through which a stream of water may be allowed to percolate from a cistern at the top, by a series of small perforations in the upper slab of the tower. This water meeting the ascending current of gas would completely dissolve it, and flowing out into a proper receptacle at the base, could be drawn away as use required. Water absorbs, at the ordinary temperature and pressure, about forty times its volume of the gas, part of which it retains even after continuous boiling.

The decomposition of the sulphate of iron and the oxidation of the sulphur, as effected during the heating of those materials in the cylinder, are represented in the annexed formula:—

$$\underbrace{\mathrm{Fe\,O,S\,O_3}}_{\text{Sulphate of iron.}} + \underbrace{\mathrm{2\,S}}_{\text{Sulphur.}} = \underbrace{\mathrm{Fe\,S}}_{\text{Sulphide of iron.}} + \underbrace{\mathrm{2\,S\,O_2}}_{\text{Sulphurous acid.}}$$

The liquid, when submitting the cloth to its action, should have a temperature of between 80° and 90° Fahr.; but if the solution is completely saturated at a temperature of 60°, then, if it were elevated to the above point, a large volume of the gas would be expelled, and prove a powerful obstacle to the success of the operation, besides involving so great a loss of labor and materials; to avoid this, all that would be required is to dilute the liquor, so that nothing appreciable will be evolved. The goods being immersed into the bath of liquid acid, are retained there till such time as by an examination they are found to be thoroughly bleached; they are then taken out, washed well with water, and, if deemed necessary, with a little potassa or soft soap.

On comparing the efficacy, economy, and facility of the operations, as required by these methods, it must be evident that the application of the liquid acid must be more satisfactory in every sense, as it is free from loss of sulphurous acid, so frequent when the bleaching is performed by bringing the gas in its elastic state in contact with the cloth; it operates equally on the fabric, which is not the case with the gas, besides performing its office in one-sixth of the time required by the other method.

The following is an enumeration of the operations to which woollen stuffs are subjected during the bleaching. Forty pieces of cloth, of forty-five to fifty yards in length, are taken and stitched endwise together; they are then singed as cotton goods, and treated as here described:—

1st. Immersed three times occasionally in a bath, formed by dissolving twenty-four parts of carbonate of soda and six pounds of soap in 120 to 140 gallons of water, heated to 100° or 105° Fahr. After each passage of the goods over the roller, the activity of the bath is renewed by adding from half to five-eighths of a pound of soap to it.

2d. Washed twice in clean water heated to the same point as the bath.

3d. Transmitted three successive times through another solution the same as above, but without any soap: after each passage, except the last, one-half to five-eighths of a pound of soda is added to the liquor.

4th. Exposed for twelve hours to the vapor of sulphur in the apparatus before alluded to, where twenty-four pounds of sulphur are consumed for the decoloration of forty pieces.

5th. Passed three times over the rollers, as in the foregoing, in a bath in which thirty pounds of soda crystals are dissolved in the same quantity of water as in the first operation: this bath stands at 120° or 125°

Fahr., and after the first and second courses of the cloth through the liquor, a little more than half a pound of crystals of the alkaline carbonate is added to it.

6th. Again bleached in the sulphuring chamber, as in the fourth operation.

7th. Exposed to a bath in which soda crystals are dissolved, as in the fifth process.

8th. Washed twice in water heated to 105° Fahr.

9th. Sulphured for twelve hours.

10th. Washed twice in tepid, and once in cold water.

11th. Tinged blue by passing the goods through a liquid impregnated with a mixture of indigo and carmine, or acetate of indigo, to suit the operator.

These, and similar methods of procedure, are usually adopted in the bleaching of woollen fabrics; but when there is a large amount of greasy and resinous impurities united with the filaments of the cloth, and this is intended for delicate colors, the scourings are not sufficiently effectual in freeing it from the last traces of those bodies which operate so injuriously in the dye-bath.

The following process is particularly adapted for goods intended for very delicate printing.

After ironing and washing with water, the raw fabrics are—

1st. Passed twice through an alkaline soap bath, heated to 140° or 150° Fahr., and composed of forty-four pounds of crystals of carbonate of soda and about nine pounds of soap in 120 or 140 gallons of water.

2d. Rinsed in warm water.

3d. Passed twice into a bath formed of twenty-two pounds of soda crystals, and heated to the same degree as in the first process.

4th. Rinsed in warm water.

5th. Passed into the sulphuring apparatus for ten hours, using twenty-two pounds of sulphur for each two hundred and fifty pieces.

6th. Rinsed in warm water.

7th. Passed twice into a bath containing about fifteen pounds of soda crystals, and heated to 140° or 150° Fahr.

8th. Passed twice into a bath containing twelve pounds of crystallized carbonate of soda, and heated as before.

9th. Rinsed in warm water.

10th. Passed into the sulphuring apparatus, using this time fifteen pounds and a half of sulphur.

11th. Passed into tepid water.

12th. Passed into a blue bath.

This terminates the operation of bleaching woollen fabrics.

Bleaching Silk.—Silk, as is well known, is the produce of the caterpillar of the silk moth; the insect spins it round itself in the shape of a hollow ball, called a *cocoon*, and there remains till it becomes a chrysalis. These cocoons are thrown into water and agitated briskly for some time, after which several of the filaments are wound up together, and this constitutes raw silk.

Silk stuffs intended to be bleached, have either already been partly bleached by the scouring operations which the silk has been made to undergo before weaving, or they are in the raw state. In the former case it is sufficient to immerse the goods for some time in running water; they are then boiled for an hour in a bath, consisting of about two ounces of soap and a pound to a pound and a quarter of bran for each piece of eight to ten yards long. The acid of the bran uniting with the excess of the alkali in the soap, prevents it from weakening the silk by dissolving it. On being taken from the bath, the goods are rinsed in water heated to 120° Fahr., and then washed well with cold water in the dash-wheel.

In the second case, the goods, after being introduced into bags, are immersed in a boiler filled with water, holding about half a pound of soap to every two pounds and a quarter of dry silk. After having heated and kept the whole in ebullition for two to three hours, the stuff is withdrawn from the bath to rinse it in running water. When well scoured it receives a second soap bath similar to the preceding, and is again scoured by the dash-wheel. The scouring being finished, the silk is passed, during ten or fifteen minutes, into a solution holding about half an ounce of crystallized carbonate of soda for each piece of silk; from this the silk is taken, washed carefully, and then passed into water slightly acidified with sulphuric acid, and after remaining here for some little time it is taken out, washed in warm water, and, finally, in running water.

Silk fabrics thus bleached are pure enough for every kind of printing in which dark or deep colors are used, such as madder, prussian blue, cochineal, amaranth, and violet; and, in fine, brown colors in general; but when it is desired to print lighter or more delicate colors, the goods should receive a slight sulphuring. In this case, liquid sulphurous acid is greatly preferable to the gas, and far more advantageous, since it may be employed in a very weak state. Care should be taken that the sulphurous acid be cautiously applied in whitening silk, as it always communicates a more or less yellow tinge, and even injures the thread or fabric after the color has been abstracted by it.—*Persoz.*

The nature of the material which covers the silk filaments was but very imperfectly understood for a long time, until the investigation of M. Roard appeared. Previous to this it was supposed to be a kind of gum, but he showed that it partook more of the nature of wax, mixed with a kind of oil and coloring matter. It forms about twenty-three or twenty-four per cent. of the weight of the raw silk. In the dry state it is friable, and of a vitreous fracture; it is soluble in water, and affords a solution which lathers like soap; when thrown upon burning coals it does not soften like wax, but burns with the exhalation of a fetid odor. Its solution, when left exposed to the open air, is, at first, of a golden yellow, but very soon becomes greenish, and in a short time putrefies, as would solutions of animal matters under similar circumstances. The yellow varnish is of a resinous nature, altogether insoluble in water, very soluble in alcohol, and contains a little volatile oil, which gives it a rank smell. The color of this resin is easily dissipated, either by exposure to the sun or by the action of chlorine; it forms about one fifty-fifth of the raw material. The same chemist has further observed that the soap bath, if of a certain density and raised to the boiling point, attacks not only the varnish but the silk itself, and destroys its lustre, rendering it dull, stiff, and colored, in consequence of the solution of more or less of its substance; this solution also takes place in other liquids, and even in boiling water. It is for this reason that silks cannot be alumed with heat; they lose some of their lustre in being dyed brown, a color which requires a boiling hot bath. Hence the greater care should be taken to have the silks submitted to the scouring, or *ungumming*, as it is called, only during such time as is requisite to remove the varnish.

According to M. **Roard**, raw silks, white or yellow, may be completely scoured in one hour, with fifteen pounds of water to one of the fibre, and a suitable proportion of soap. The soap and silk should be put into the bath half an hour before its ebullition, and the latter should be turned about frequently. Dull silks, in which the varnish has undergone some alteration, never acquire a fine white till they undergo the operation of sulphuring. Exposure to the air is said to be resorted to by the Chinese with a good effect.—*Ure.*

It appears that the Chinese use no soap, but a species of bean, wheat flour, common salt, and water. According to **De Grubbens**, the proportions used for the bath are, five parts of beans, five of salt, six of flour, and twenty-five of water. The elimination of the impurities is not easily accounted for in this case, but it is possible that some acid may have been formed, which would soften the gum and facilitate its removal in the subsequent washing.

Chevalier **Claussen's** process for cleaning silk is—

1st. Boil it in a soap composed of butter and caustic potash or soda, for two or three hours.

2d. Steep in a solution of carbonate of soda or ammonia.

3d. Sour in a weak solution of sulphuric or muriatic acid.

For bleaching silk—

1st. Steep in carbonate of soda or ammonia.

2d. Steep in a solution of sulphurous acid in water, or expose it while wet to the fumes of sulphur.

An artificial shade is sometimes communicated to the silk by impregnating the bath with certain colors. These shades are distinguished by the term china white, azure white, silver white, thread white, *et cetera*, and are communicated by the addition of annato to the bath for china white, or by the addition of litmus or indigo in various proportions, as one or other of the shades is desired.

In the foregoing pages the principal applications of bleaching are described; but besides these, others are resorted to for whitening textile materials, which are used chiefly by the calico printers. They consist principally in removing the colors taken up in the dye-bath from certain parts of the cloth; hence they are called discharges.

Chromic acid, bichromate of potassa, and the protochloride of tin, are employed on these occasions, but their action on the coloring matter has not been very minutely studied. It is certain that the former two bodies generally operate by oxidizing the color, but the chloride of tin is supposed either to abstract oxygen and form more or less bichloride, or to enter into combination with the coloring matter, forming a colorless body.

There are other materials from which it is absolutely necessary to remove the coloring matter, before they can be used in the manufacture of certain articles. Such is the case with fatty bodies, especially those used in the formation of candles, straw for millinery purposes, and the material for the manufacture of paper.

The method of procedure for bleaching the first two will be given in the treatise upon candles, whilst the processes usually followed in the whitening of straw and rags for paper will here be briefly explained.

A very considerable trade is carried on in England by her own people in this department. In Tuscany, where straw for artistic purposes is prepared to a large amount, it is selected whilst the wheat is bearded and the grains are in a soft milky state. The corn is sown very thickly, and the straws are thin, short, or in a dwindled condition. A careful culture insures the requisite degree of fineness in the material. It is spread out for three or four days, and as soon as the sap is dried up, it is tied in bundles and stacked, for the purpose of expelling the moisture. Another exposure for some time in the meadows to the dew and atmosphere, acts upon the coloring matter and promotes the bleaching. Before the decoloration is entirely effected, it is necessary to turn the straw several times, and to moisten it occasionally with water. When thoroughly exposed, the lower joints of the straw are cut off, and the parts chosen for use are acted upon by steam, which dissolves most of the remaining coloring matter, and then it is submitted to the vapor of sulphur to decompose the residue.

In this country the straw is prepared by acting upon the ordinary materials; first, with a boiling solution of caustic soda, by which a considerable portion of the organic matter and natural varnish is disintegrated; after this it is washed well to remove all the material which the alkali dissolves, and then exposed to the action of the vapor of sulphur, or to bleaching powder, in confined vessels. Care should be taken that the sulphuring does not produce any charring of the straw by its too rapid combustion, for such cannot be remedied when once it has taken effect. Three or four hours' exposure to sulphurous acid, and about the same time to the solution of bleaching powder, is sufficient to remove the stains remaining.

Kurrer states that the straw may be economically whitened by being steeped repeatedly in boiling water and very weak alkali, and after the whole of the soluble matters are in this way removed, treating alternately with very dilute solutions of oxychloride of calcium and sulphurous acid vapor till the decoloration has been effected. This method, though tedious, is said to be very effectual for divesting the straw of its natural varnish, which renders it brittle.

Materials for Manufacture of Paper.—This indispensable commodity, as is well known, is prepared from rags of various descriptions. Although this branch of manufacture is eminently interesting, and illustrates the benefits conferred upon society by genius and skill, yet, as it is chiefly mechanical, it does not fall within the province of a chemical treatise, except in regard to the abstraction of the color from the rags, and a few other particulars which, although apparently of minor importance, are nevertheless requisite to the beauty and finish of the article. The materials or rags, which, as before stated, are of every shape, pattern, and color, are assorted according to their quality, and after they have been operated upon in various ways, by which they are freed from dirt as much as possible, and reduced to a kind of magma, a clear solution of bleaching powder, the strength of which is regulated by the color of the rags, is poured in and intimately mixed with the pulp by machinery. After an hour's comminution in this solution, the mass is well washed with water to take up all the soluble matter. About two to four pounds weight of bleaching powder are proportioned to a hundredweight of rags for removing the coloring matters; but sometimes, when the rags consist of dyed or printed cotton, the quantity of bleaching powder is increased to as much as eight pounds, and the agitation is continued for a longer time.

The washing is resorted to after the bleaching powder has acted upon the goods. Hydrochloric acid is supposed to be sometimes added, in order to insure the removal of the inorganic salts more completely than if only water were used. Unless the whole of the lime salt is separated from the pulp, the paper is liable to assume a brownish color. The French manufacturers discharge the coloring matter by chlorine gas, and in consequence of this their paper retains its beautiful whiteness. In this case, the chlorine acts upon the assorted rags after they have been well washed with water, boiled in alkaline lie, torn asunder into fibrous fragments, and submitted to a strong pressure. The damp cakes thus formed are broken up and placed in large rectangular wooden cisterns, then the chlorine conducted from the stills or generating apparatus by tubes inserted in the lid of the vessels. In a short time the chlorine permeates the mass and destroys the color. Many affirm that bleaching with oxychloride of calcium, performed with care, gives a paper of greater body and durability than when chlorine is used, as it does not destroy any of the fibre; the latter is preferable, however, when perfect freedom from color is desired.

Much interest is attracted by the paper manufacture at present in consequence of the growing scarcity of materials, and premiums have been offered to those who may be fortunate enough to hit upon a suitable substitute for rags. Any matter affording woody fibre in large quantities, and capable of being reduced to a minute state of division and bleached with facility, is adapted for the manufacture of paper; but as rags were the richest source of this substance and easily procured hitherto, no search was ever made for a substitute. Now, however, attention is unceasingly given to this subject, and it is hoped that the result may prove another triumph. Fibres suitable for paper pulp are found in a great many plants, but the chief difficulty has hitherto been to bleach them. Of plants adapted for this purpose, not a few are indigenous; among others of this class—exclusive of flax and hemp—may be mentioned the pine, birch, poplar, willow, lime, nettles, hops, heaths, and several reeds and straws. Of exotics, the jute—*Corchorus indicus*—espartum, pineapple, plantain, palms, and a great many others, produce suitable fibres. The difficulty of bleaching these materials seems to be overcome by Chevalier CLAUSSEN'S process, already described. This gentleman presented, at the Great Exhibition in 1851, samples of paper pulp and paper from pinewood, espartum, and jute, bleached by his patent process. He thinks that the paper manufacture ought to be divided into two distinct branches, one chemical, and the other mechanical—the first embracing the manufacture and bleaching of pulp, and the second the conversion of pulp into paper. By division of labor, perfection and cheapness would be attained, and less capital required. To produce paper pulp from pinewood by CLAUSSEN'S patent, it must be crushed between heavy rollers, and boiled under steam pressure with caustic lime water, steeped in carbonate of soda, soured in hydrochloric acid, and then bleached by the process recommended by the same authority.

Many other substances have been announced, but sufficient guarantee of their adaptation has not yet been given to establish their value for this purpose.

BLEACHING POWDER.—*Chloride of lime, bleaching salt; chlorure de chaux*, French; *bleichkalk, bleichpulver chlor-kalk*, German.—The foregoing names are given to the compound about to be described, to denote its effects; but they do not, even in a remote degree, intimate its chemical constitution, which ought always to be distinguishable from the designations of such bodies. It is called *hypochlorite of lime* by many chemists, from the fact that they conceive it to be a compound of lime, CaO, with hypochlorous acid, ClO, but the composition of bleaching powder does not admit of this formula. The Editor, with some others, thinks it more probable that it is a compound of the type of binoxide of calcium, in which one equivalent of the oxygen is replaced by chlorine, as the annexed formulæ illustrate—

$$\underbrace{\mathrm{Ca}\left\{\begin{matrix}\mathrm{O}\\ \mathrm{O}\end{matrix}\right.}_{\text{Binoxide of calcium.}} \qquad \underbrace{\mathrm{Ca}\left\{\begin{matrix}\mathrm{O}\\ \mathrm{Cl}\end{matrix}\right.}_{\text{Bleaching powder, or oxychloride of calcium.}}$$

Others, again, assert that the compound is a hypochlorite of lime united to an equivalent of chloride of calcium; thus—

$$\mathrm{Ca\,O,\ Cl\,O + Ca\,Cl.}$$

But the fact that chlorine is liberated when this body is triturated with chloride of calcium, disagrees very much with the latter theory.

The introduction of this compound has been already alluded to under Bleaching, and its merits in that art are well appreciated, as best appears from its universal application. Its preparation in the laboratory is simple, merely by passing chlorine gas over bihydrate of lime, as long as the latter acquires more weight.

The following are a few experiments performed by the Editor in 1837, to elucidate the composition of bleaching powder.

1*st Experiment.*—Desiccated chlorine gas was passed over pure caustic lime—CaO—during four days; nevertheless, it did not acquire any increase of weight, which is conclusive proof that anhydrous lime will not combine with chlorine gas.

2*d Experiment.*—In this experiment, hydrate of lime, Ca O, H O, was exposed to chlorine gas, till the augmentation of weight ceased. The analysis of the product showed that the lime had absorbed 36·2 per cent. of the gas.

3d Experiment.—An equivalent of hydrate of lime—Ca O H O = 37—was taken, and mixed intimately with an equivalent of water—H O = 9—and this mixture exposed to the gas, as in the other instances. The additional atom of water caused the absorption of the gas to the extent of forty-three to forty-four per cent., as the analysis shows:—

	Atomic weight.	Theory.	Found.	
1 Eq. of chlorine, ...	35·50 ..	43·558 ..	43·00 ..	44·00
1 Eq. of lime,..........	28·00 ..	34·358 ..	— ..	—
2 Eq. of water, ...	18·00 ..	22·034 ..	— ..	—
1 Eq. bleaching powder,	81·50	100·000	—	—

From this it will be seen that the additional atom of water causes the absorption of from seven to eight per cent. more than the hydrate.

4th Experiment.—Mixed intimately equivalent proportions of protohydrate of lime and chloride of sodium, and submitted the mixture to a stream of chlorine gas. In this experiment, the salt had the same influence in solidifying the chlorine as the second atom of water in experiment 3. The chloride of sodium could not have acted chemically, but mechanically, in this instance; so also must the second equivalent of water in the other experiment; for it is no more essential to the formation of bleaching powder than the chloride of sodium, or any other salt.

This experiment was repeated with chloride of barium, Ba Cl, chloride of potassium, K Cl, sulphate of lime, Ca O, S O_3, sulphate of baryta, Ba O, S O_3, crystallized sulphate of soda, Na O, S O_3 + 10 aq., caustic lime, Ca O, *et cetera;* and the results showed that any one of these compounds caused the protohydrate of lime to unite with nine or ten per cent. more of the gas than it would have done alone.

From the above, bleaching powder containing 36 per cent. of chlorine, appears to be an oxychloride of calcium, with an essential atom of water, and that which contains forty-five per cent. an oxychloride, containing an essential and likewise a mechanical equivalent of water. When the latter compound is triturated with perfectly dry chloride of calcium, a quantity of chlorine is liberated. The reason of this is, that the chloride of calcium being very hygroscopic, absorbs the second atom of water, and the amount of chlorine, which this held mechanically, is liberated.

The chlorine for these experiments was prepared by adding hydrochloric acid to chlorate of potassa; the reaction that succeeded is—

$$\underbrace{6\,\mathrm{H\,Cl}}_{\text{Hydrochloric acid.}} + \underbrace{\mathrm{K\,O,\,Cl\,O_5}}_{\text{Chlorate of potassa.}} =$$

$$\underbrace{6\,\mathrm{H\,O}}_{\text{Water.}} + \underbrace{\mathrm{K\,Cl}}_{\text{Chloride of potassium.}} + \underbrace{6\,\mathrm{Cl}}_{\text{Chlorine.}}$$

Before the gas came in contact with the lime, it was passed first through water, and then through two large tubes filled with fragments of fused chloride of calcium, so that it was pure and dry.

This compound may be easily prepared in solution, by transmitting chlorine gas through water holding hydrate of lime in suspension; the lime dissolves, and a true atomic combination is formed, unlike what happens when the gas is passed over the powder, for in this case often sixteen to eighteen per cent. of it is in a free state. It would not be convenient, however, to have the substance prepared in the liquid way, as the difficulties of its transport would far surpass the advantage of the body having greater bleaching powers; besides, it is readily decomposed in this state.

In making bleaching powder, the labor may be said to be divided into three stages: firstly, the preparation of the lime; secondly, the generation of the gas; and thirdly, the combining of the two.

PREPARATION OF THE LIME.—Unless lime of the best quality be procured, the salt prepared from it will be very inferior in color, and, in fact, cannot be used in a great many cases. Such limestones as contain iron, alumina, or magnesia should be rejected, and that which is quite white selected. It ought to be used as speedily as possible after burning, lest by exposure it might reunite with carbonic acid in greater or less quantity, and form carbonate of lime, which does not combine with the chlorine. After the lime is well burned, it is brought to the screening department and slacked. This is an operation which, though simple, requires some care in proportioning so much water only as will cause the lime to crumble into a fine powder. About five gallons of water to the hundredweight of quicklime will best answer, as well for insuring the slaking of the compound as for giving a rich product. A stratum of about half a foot in thickness is spread upon the floor of the shed, and the water equally sprinkled on through the rose of a large watering-can; and, if necessary, the workmen turn it so as to bring every part in contact with the water. After it has been reduced to a fine powder, it is then screened or sifted through fine wire gauze, or hair-cloth, for the purpose of separating any lumps. The fine powder that falls through is now in a fit state to be impregnated with the gas, which is prepared in the manner about to be described.

PREPARATION OF THE CHLORINE.—Many methods may be resorted to for making chlorine gas, but in large factories those adopted are the following:—Either peroxide of manganese is acted upon at once by hydrochloric acid in a convenient apparatus, or it is mixed with common salt, and the mixture decomposed by sulphuric acid. From either of these chlorine is evolved, as the annexed formulæ explain:—

$$\underbrace{\mathrm{Mn\,O_2}}_{\substack{\text{Peroxide of}\\\text{manganese.}}} + \underbrace{2\,\mathrm{H\,Cl}}_{\substack{\text{Hydrochloric}\\\text{acid.}}} = \underbrace{\mathrm{Mn\,Cl}}_{\substack{\text{Chloride of}\\\text{manganese.}}} + \underbrace{2\,\mathrm{H\,O}}_{\text{Water.}} + \underbrace{\mathrm{Cl}}_{\text{Chlorine.}}$$

$$\underbrace{\mathrm{Mn\,O_2}}_{\substack{\text{Peroxide of}\\\text{manganese.}}} + \underbrace{\mathrm{Na\,Cl}}_{\substack{\text{Chloride of}\\\text{sodium.}}} + \underbrace{2\,\mathrm{H\,O,\,S\,O_3}}_{\text{Sulphuric acid.}} = \underbrace{\mathrm{Mn\,O,\,S\,O_3}}_{\text{Sulphate of manganese.}} +$$

$$\underbrace{\mathrm{Na\,O,\,S\,O_3}}_{\text{Sulphate of soda.}} + \underbrace{2\,\mathrm{H\,O}}_{\text{Water.}} + \underbrace{\mathrm{Cl}}_{\text{Chlorine.}}$$

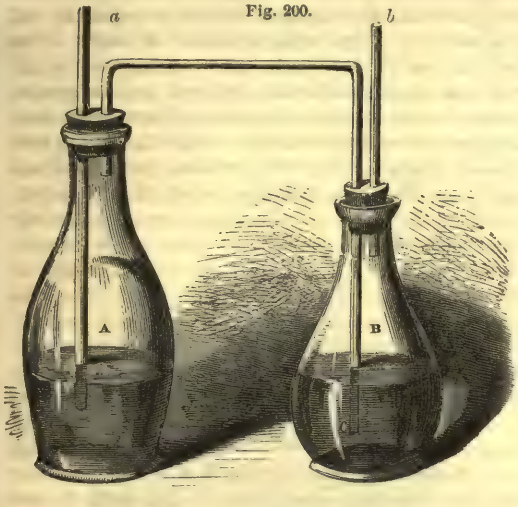
The former of these equations is the most economical, especially if carbonate of soda be manufactured on the same premises; but very often, when this is not the case, the latter is substituted. Particular regard must be paid in this department to the purity of the materials, especially of the peroxide of manganese, as the gas disengaged will be proportionate to the quantity of pure peroxide contained in it. This mineral is found in many localities on the Continent, but principally in the Hartz and Piedmont; it is also obtained from Thuringia and Moravia in large quantities. A good deal is raised in a few of the mines of Devonshire and Cornwall, in England; and in Wicklow, in Ireland, it is found in limited quantities. The English miners call it *black wad*, and the Germans give it the name *braunstein*.

The best and simplest method for testing the quality of manganese ore is that of FRESENIUS and WILL. It consists in reducing it to very fine powder, weighing out a certain portion, and introducing it into the flask, A, in the annexed Fig. 200; two and a half times the weight of the manganese are then taken of neutral oxalate of potassa, and about two ounces of water are poured into the same bottle, after which the flask, B, is filled to about two-thirds of its capacity with strong sulphuric acid; both flasks are next closed by the doubly perforated corks, into which the tubes are inserted, as represented in the figure. The apparatus is now wiped dry, and placed upon the pan of the balance, and the weight noted; the tube, *a*, is then closed by a piece of sheet india-rubber, and suction is applied at the tube, *b*; by this means a partial rarefaction of the air in the flasks is produced, and on withdrawing the mouth from *b*, the influx of air forces a portion of the acid over through *c* into A, which, coming in contact with the manganese and potassa salt, evolves carbonic acid by the oxidation of the oxalic acid in the oxalate, thus:—

$$\underbrace{MnO_2}_{\text{Peroxide of manganese.}} + \underbrace{KO, C_2O_3}_{\text{Oxalate of potassa.}} + \underbrace{2\,HO, SO_3}_{\text{Sulphuric acid.}} = \underbrace{MnO, SO_3}_{\text{Sulphate of manganese.}}$$

$$+ \underbrace{KO, SO_3}_{\text{Sulphate of potassa.}} + \underbrace{2\,HO}_{\text{Water.}} + \underbrace{2\,CO_2}_{\text{Carbonic acid.}}$$

Fig. 200.



This gas escapes through the tube, *c*, and the sulphuric acid in the flask, B, and finally by the short open tube into the air. When the generation of the gas takes place but feebly, a fresh quantity of sulphuric acid is forced over, and the operation thus continues till all the black mineral is decomposed, and no more carbonic acid is generated, even in the presence of an excess of sulphuric acid. The sheet of caoutchouc is then removed from the tube, *a*, and suction applied at *b*, till all the carbonic acid in the flask, A, is carried off. A careful wiping of the flasks is now necessary, after which they are weighed. The results of the former and this weighing differ directly according to the weight of carbonic acid which has been formed from the oxalic acid, and the second atom of oxygen in the peroxide, as seen in the equation—

$$\underbrace{C_2O_3}_{\text{Oxalic acid.}} + \underbrace{O}_{\text{Oxygen.}} = \underbrace{2\,CO_2}_{\text{Carbonic acid.}}$$

From this, it is clear that every equivalent of peroxide of manganese operated upon in the way described, gives rise to two equivalents of carbonic acid; and as the atomic weight of these is the double of 22—this being the equivalent of the dry and pure gas—or 44, which is also the atomic or equivalent weight of the peroxide, it is evident that the weight of the carbonic acid ascertained is the same as that of the pure peroxide required to produce it. *Exempli gratia*—If forty grains of the binoxide acted upon, in the apparatus described, by sulphuric acid in the presence of one hundred grains—two and a half times its weight—of oxalate of potassa, lost twenty-five grains, this would show that the sample contained twenty-five grains of pure peroxide, or 62·5 per cent. In testing manganese in this way, it is necessary that the tubes and corks should fit air-tight, and that the oxalate should be neutral and free from carbonate. The carbonic acid gas, as it passes through the sulphuric acid, is divested of any moisture which might have accompanied it from the flask, A. Sometimes oxalic acid is used instead of oxalate of potassa; but as it gives off carbonic acid immediately on coming in contact with the manganese and water, more or less of which escapes before the apparatus is weighed, the results are not so accurate as when the oxalate of potassa is used. When, however, the oxalate is not at hand, the oxalic acid may be used in the proportion of one part and a half to one of manganese, taking the precaution of weighing the apparatus as quickly as possible.

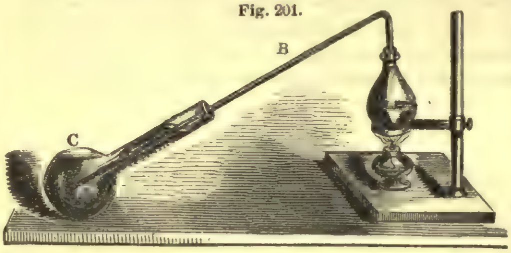
Many other methods are resorted to for testing the value of the mineral, the most frequent being that by which arsenious acid is converted into arsenic. A certain weight of the ground mineral is taken and acted upon by hydrochloric acid, which causes the liberation of chlorine, and the formation of protochloride of manganese, as annexed:—

$$\underbrace{MnO_2}_{\text{Peroxide of manganese.}} + \underbrace{2\,HCl}_{\text{Hydrochloric acid.}} = \underbrace{MnCl}_{\text{Chloride of manganesium.}} + \underbrace{2\,HO}_{\text{Water.}} + \underbrace{Cl}_{\text{Chlorine.}}$$

A solution of potassa absorbs the gas thus liberated, and forms a bleaching compound, which is afterwards tested as to the amount of chlorine by the arsenious acid solution. The operation mentioned here is best conducted as represented in the annexed woodcut—Fig. 201.

The mineral being finely ground, a hundred grains of it are taken and introduced into the flask, A, into which about three ounces of concentrated hydrochloric acid have been previously poured; the tube and cork, B, are then fitted to it without delay, and the evolved chlorine received in the flask, C, where it is absorbed by the solution of potassa. The flask should be filled so that the liquor may reach a considerable way up into the neck, as shown in the figure. When the bubbles of gas pass over into the liquid, any part which is not absorbed immediately rises—in consequence of the flask being inclined to the upper part of the bulb—and is there subjected to the hydrostatic pressure of the column of liquid in the neck of the flask, which is very favorable to the whole of the gas being absorbed. A gentle heat is communicated to the bottom of the flask, A, by a lamp, till the whole of the manganese is decomposed, and the liquor slowly and progressively begins to boil. At this period, if no more chlorine is evolved—this is known by the rising of the alkaline liquor in the tube—the cork is quickly removed from the flask and the tube washed with distilled water, adding these washings to the solution in C, which is transferred to a beaker or testing glass. A test solution of arsenious acid is made of such strength, that one division of it will correspond to one grain of peroxide of manganese. This liquor is prepared by dissolving 123·8 grains of pure arsenious acid in about two ounces of strong hydrochloric acid, entirely free from nitric or sulphurous acids, and the liquid diluted to fill the burette up to zero, the whole being colored by a few drops of a solution of indigo. The solution is then poured into the chlorine liquor gradually as long as the blue color is destroyed; when this no longer happens, the number of measures of the test solution added is read off, which number corresponds to the quantity of peroxide in the sample.

Fig. 201.



The principle of this method is, that every equivalent of arsenious acid—99—requires two of chlorine—71—for its oxidation into arsenic acid—115. One hundred parts of pure peroxide of manganese, when acted upon with hydrochloric acid, liberate 80·7 of chlorine gas, and these oxidize 123·8 parts of arsenious acid, according to the foregoing statement. So long as available chlorine remains in the liquor, it operates upon the indigo and destroys its color. As soon as the whole is combined, the blue remains unaltered. To observe it more carefully, the beaker should be placed upon a sheet of white paper, and on looking vertically through it the blue shade will be immediately perceived. The change effected in the oxidation of the arsenious acid is represented in the annexed:—

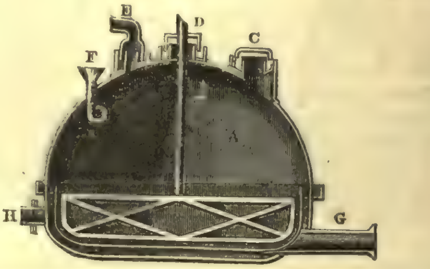
$$\underbrace{As\,O_3}_{\text{Arsenious acid.}} + \underbrace{2\,Cl}_{\text{Chlorine.}} + \underbrace{2\,H\,O}_{\text{Water.}} = \underbrace{As\,O_5}_{\text{Arsenic acid.}} + \underbrace{2\,H\,Cl}_{\text{Hydrochloric acid.}}$$

Other forms of analysis besides the above are resorted to for examining the commercial value of manganese, but as they are the same in effect as those to which recourse is had for the estimation of the chlorine in bleaching powder, they need not be here described.

Manufacture.—The alembics, or vessels wherein the chlorine is generated, are of various descriptions, some of them being composed of strong sheet-lead, others of cast-iron, while some are constructed of slabs of stone grooving into one another, and well cemented by a good luting; those which are partly of lead and cast-iron are the most generally adopted.

Fig. 202 represents a section of one of these stills. A is the still: it consists of two parts, the lower one, B, being enclosed in a jacket of cast-iron, and steam injected in the intermediate space for the purpose of heating the contents. Sometimes the lower half is constructed of cast-iron, having a groove in the upper part, to which the top part is secured by a coat of good cement. In this case, heat is communicated by means of a slow fire placed under the cast-iron bottom. In the dome of the still there are four openings: into one, C, the solid materials employed are introduced, whilst the acid is added through the funnel opening, F. The gas evolved passes off by the pipe, E, to the purifier and chamber, where it is combined with the lime, and the shaft of the agitator passes up through D.

Fig. 202.



Steam is introduced from an ordinary boiler through the pipe, H, and the materials, after the whole has been decomposed, are drawn off by the pipe, G. The four openings, C, D, E, F, are secured by water lutes, capable of bearing a pressure greater than that which is required in the chamber where the saturation takes place.

When operations are carried on, the manganese and salt are introduced in the ratio of a hundred parts of the former to a hundred and fifty of the latter; about a hundred and eighty-five of sulphuric acid, specific gravity 1·6, are then added, and the covers luted on by pouring water into the several receptacles after the lids have been closed. The fire is then lighted, or the steam introduced, as the case may be, till the temperature of the interior is raised to 180° Fahr., keeping the agitator worked from time to time to raise the manganese, which readily subsides in contact with the acid. In the proportions given above, the equivalents of the pure materials are taken, but commercial peroxide of manganese is never pure, sixty to seventy-five per cent. being its average value; hence it is necessary to proportion the salt and acid, in the ratio of the above numbers, to the per centage of pure peroxide. Where carbonate of soda or sulphuric acid is manufactured, salt is rarely used, but the hydrochloric acid given off from the decomposition of this body by the sulphuric acid in the formation of GLAUBER'S salt—sulphate of soda.

By knowing the strength of the acid and the richness of the manganese ore operated upon, the manager can apportion these to one another, so as to bring about a perfect decomposition. One part of pure peroxide of manganese requires about four and a quarter parts of acid, specific gravity 1·18; this amount will not be used in working all kinds of ores, for they contain considerable portions of siliceous matters which remain insoluble, but the iron and other impurities, although they do not contribute in the least to the elimination of the chlorine, must be acted upon with the manganese. On this account it is necessary to know the quantity of metallic oxides with the peroxide in the manganese, and proportion the acid so as to prevent loss, or at least that a great excess of the latter may not be employed.

The combination of the chlorine and hydrate of lime, which is the last stage of the manufacture, will now be considered. Various contrivances have been, and are occasionally resorted to, for uniting these two bodies, but the one which is generally adopted is represented in Fig. 203. The pipe, E E, conducts the gas into the leaden chamber, I, which may be divided into several compartments, according to the number of stills working. On the floor of this chamber, the screened lime is strewn, and furrowed by means of a rake, so as to expose a greater surface to the gas.

In the doors, K K, some panes of glass are fixed, as well for admitting light into the chamber, that the workmen may see to spread the lime properly, as for observing how the absorption progresses. L L are openings at the base of the chambers, through which the handles of rakes work; they are introduced to stir the powder and expose a fresh surface to the gas, till it becomes thoroughly saturated. The practice of turning the semi-formed bleaching powder at regular intervals by spades, is found to answer best, but then the operation is such that very few can withstand it, on account of the vapors of chlorine. Sometimes the powder is laid on wooden trays, fixed in layers, one above another, till the compartment is charged, and the gas admitted at the top of the chamber as described. The object of this is to produce a richer product, as a greater surface is presented to the gas, and consequently a larger volume is taken up in a shorter period. As the combination occasions some heat, the rapid absorption would develop a considerable rise of temperature, which might decompose some of that already formed; and this is probably one reason why large manufacturers prefer constructing low chambers, and spreading the powdered lime upon the ground floor; for, in this case, although the gas unites with the metallic oxide less rapidly than if a thinner but more extended stratum were exposed, still the elevation of temperature is checked, and the work goes on steadily. The heat of the chamber should never exceed 100° to 110° Fahr., lest, instead of obtaining an oxychloride, chloride of calcium should be produced.

Fig. 203.

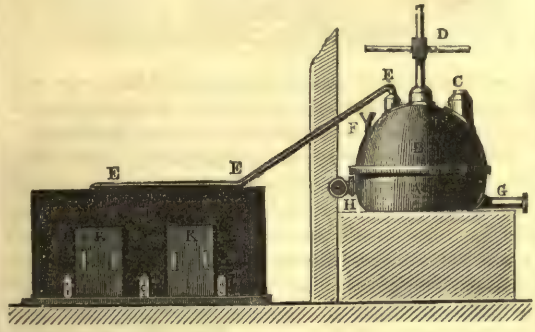
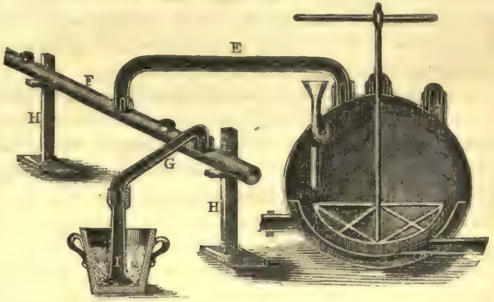


Fig. 204



The period required for saturating the lime extends to thirty-six or forty-eight hours; but sometimes, when the site is cool and the layer of powder is not very thick, it is finished in twenty-four or thirty hours.

BOOTH suggests that, instead of conducting the gas into chambers, such as those described, a range of pots ought to be provided similar to that sectionally represented in Fig. 204. In each of these an inverted leaden funnel, I, is placed, the lower rim of which has a waved outline, in order to favor the escape of the gas. The powdered lime is shaken loosely around the funnel, and the vessel closed with a wooden cover. Chlorine is conveyed from the stills by the pipe, E; this is connected with another, F, supported upon stands, H H, by a water lute, and a communication from the latter is opened into the several pots by pipes, G, secured as the preceding to the funnel, I. Twenty, thirty, or forty such vessels are enclosed by low walls, and, in order to prevent a rise of temperature, are surrounded by cold water. By such a contrivance the heat never exceeds 110° Fahr. The chloride of lime made in pots is much harder and denser than that made in chambers.—*Booth.*

Mr. C. T. DUNLOP'S patent method of liberating chlorine from common salt, by means of nitrate of soda and sulphuric acid, and carried out on a large scale by Messrs. TENNANT of Glasgow, is as follows:—

When one equivalent of the nitrate and three of salt are decomposed by sulphuric acid, the gaseous products are chlorine, and nitrous and hydrochloric acids.

The process is conducted in iron cylinders, lined with bricks; each cylinder is six feet in diameter and seven in height, and is capable of holding twelve hundredweight of nitre, with the requisite salt and acid.

A heat of 400° or 500° Fahr. has been found to be sufficient, and a charge may, at this temperature, be worked off in about thirty-six hours.

The acid—of about 150° Twaddle—is employed in sufficient quantity to form a bisulphate of soda, which, when the nitrate and salt have been fully decomposed, is tapped off in the liquid state into a furnace containing common salt, and thus the excess of acid is made use of, and a neutral dry sulphate obtained.

The gases are passed through a common **WOULFF'S** apparatus, consisting of five bottles made of lead, each of which is filled with sulphuric acid to the depth of twenty-four inches. This large amount of acid is employed for the purpose of supplying a pressure sufficient to keep down the violent ebullition which ensues, on adding the acid to the salts in the cylinder.

In passing through the condensers, the nitrous acid gas is absorbed, and the chlorine and hydrochloric acid pass together through an ordinary tower, where the latter is taken up by water, and the former goes on to the chamber for making bleaching powder.

The nitrous sulphuric acid produced, is used instead of nitre in the manufacture of sulphuric acid.

Messrs. **TENNANT** decompose about eight tons of nitre per week, which produce about twelve of good bleaching powder.

The expense of this process is not greater for labor and fuel than the ordinary sulphate method; the heavy cost of the nitrate, however, would leave no profit on the bleaching powder, were it not that the nitrous acid produced supplies the place of nitrate of soda in the manufacture of sulphuric acid.

Many persons, as already alluded to, prefer making a liquid to a solid chloride, partly on account of obtaining a richer product, and also for the saving of trouble in dissolving the latter when it is required for use.

Fig. 205.

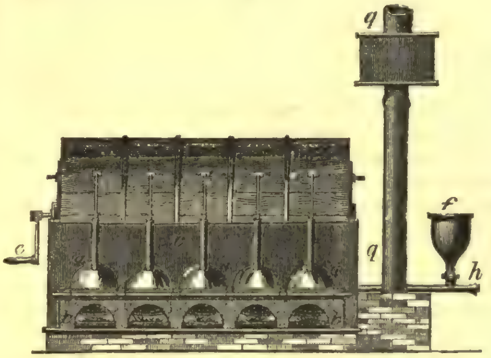
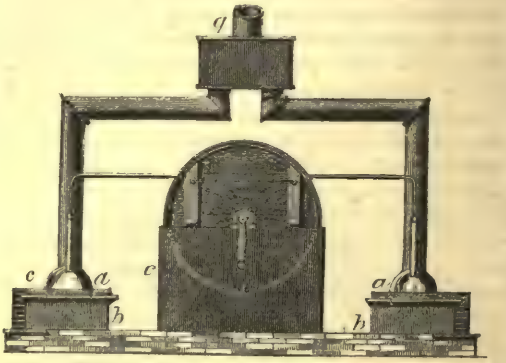


Fig. 206.



Figs. 205 and 206 represent the apparatus employed by the manufacturers and bleachers of Mulhouse for preparing this liquor; the first is a side, and the second an end elevation. In these figures, *a a a*, are glass balloons or globes, placed upon sand-baths, which are fixed in masonry or brickwork, and heated by the furnace, *b b*, the flue of which circulates around each globe, and terminates in the pipe, *q q*. The manganese, salt, and sulphuric acid, or manganese and hydrochloric acid, are introduced into these vessels, and the gas as it is developed is discharged into the trough, *c*, by glass tubes. This trough is made of a kind of siliceous freestone, well annealed, and covered over with boards coated interiorly, and cemented together with bituminous mastic. The cover is fixed into grooves in the walls of the concave part, and secured against chlorine escaping by cement, *et cetera*. In the interior of this vessel a horizontal cylinder, having a number of protruding arms with boards attached in the form of a helix, is placed; it is fastened air-tight, and turned by the winch, *e*. The milk of lime is introduced by the funnel, *f*, and the chloride of lime liquor drawn off at *h*.

Care should be taken to avoid subjecting the glass globes to pressure, as much as possible, and for this reason the end of the pipes should not be immersed in the menstruum, but should terminate above it, and make amends for the defect by presenting a larger surface to the gas, and maintaining this by proper agitation. If, instead of the glass globes, the ordinary leaden still of the manufacturers of this country were substituted, and an intermediate vessel containing water were furnished for depriving the gas of acid vapors, the arrangement would, in the Editor's opinion, be more eligible, and less chloride of calcium would be formed.

The characteristics of good dry bleaching powder are, that it is of a uniform white color, not lumpy, possessing a strong odor of chlorine, and slowly deliquescent in the air; it forms a smooth paste with water, in twenty parts of which it dissolves, leaving but a little residue. The salt should always have an excess of lime, wherewith to neutralize any hydrochloric acid that may form by the decomposition of portions of the bleaching compound, and thus remove the cause of a more rapid change. This excess of hydrate of lime does not, however, prevent the decomposition, for when it is retained for some time a great loss is experienced in the amount of available chlorine which it originally contained; heat effects the same metamorphosis, the products being, according to the observations of **MORIN**, eighteen equivalents of chlorine, producing with the lime seventeen equivalents of chloride of calcium and one of chlorate of lime, and disengaging twelve equivalents of oxygen gas.

The bleaching properties of this salt have been already alluded to, and are the most important. It is, however, highly beneficial in other respects—for example, in the production of chloroform, and as a disinfectant.

The operation of testing the value of bleaching powder has been termed *chlorometry*. With the introduction of bleaching into the various trades wherein it is now applied, it became a matter of considerable importance to be able to ascertain, with accuracy and facility, the amount of chlorine available for the purposes for which it was intended. Without going into unnecessary details, the Editor will here describe such methods of analysis as will be found most applicable for the estimation of the chlorine. It has been shown already, that pure bleaching powder corresponds with the formula—

$$\mathrm{Ca}\left.\begin{matrix}\mathrm{O}\\ \mathrm{Cl}\end{matrix}\right\}\mathrm{H\,O},$$

the equivalent of which is 72·5, or, if represented by the equation, $\mathrm{Ca\,Cl} + \mathrm{Ca\,O, Cl\,O} + 2\,\mathrm{H\,O}$, is 145. According to theoretical calculations, either of these formulæ affords 48·96 per cent. of chlorine gas; however, this state of purity is never attained, nor is it desirable that it should be, since the compound is so prone to decomposition unless there is some uncombined lime to unite with the hydrochloric acid which is spontaneously generated. This is the reason why the best commercial product rarely exceeds thirty-six per cent., but generally it averages thirty to thirty-three. The usual analytical methods for arriving at the knowledge of the total amount of chlorine in the bleaching powder are practically not applicable, since the sample, if it had been exposed for a considerable period to the air, or had experienced a high temperature, might retain some or all of the chlorine, in the shape of chloride of calcium or chlorate of lime, and yet be of no service whatever to the manufacturer; in fact, it would be productive of much injury, especially if the latter salt were present, for reasons which have been already adduced. As chlorine is a powerful oxidizing agent, it will be readily conceived that the mode of analysis must be carried out through the action of this element in raising some given body to a higher state of oxidation.

This is usually done by a volumetrical course of experiments, but it may be effected by weighing in one instance, namely, by conducting the chlorine evolved from a known weight of the sample by hydrochloric acid into a solution of chloride of barium, impregnated with sulphurous acid. In this case, the chlorine brings about the oxidation of the sulphurous into sulphuric acid, which precipitates with the baryta. From the weight of the sulphate of baryta after being dried and ignited, the chlorine is calculated; for every 116·5 parts of the salt, one equivalent corresponds to 35·5 of chlorine. The reaction in the preceding is as follows:—

$$\underbrace{\mathrm{Ba\,Cl}}_{\text{Chloride of barium.}} + \underbrace{\mathrm{S\,O_2}}_{\text{Sulphurous acid.}} + \underbrace{\mathrm{H\,O}}_{\text{Water.}} + \underbrace{\mathrm{Cl}}_{\text{Chlorine.}} = \underbrace{\mathrm{Ba\,O, S\,O_3}}_{\text{Sulphate of baryta.}} + \underbrace{\mathrm{H\,Cl}}_{\text{Hydrochloric acid.}}$$

The volumetrical method always consists in dissolving equivalents of those salts which are to be brought to a higher state of oxidation by the chlorine of the bleaching compound, or multiples or semimultiples of their equivalents, in a known volume of liquid, and adding these solutions from a measured glass to the dissolved bleaching salt, or inversely, till by an appropriate test it is shown that the chlorine has entirely been taken up, or that the substance is fully oxidized. When this point is gained, from the knowledge of the weight of the substance in the standard solution operated upon, and the weight of the sample required to effect oxidation, the per centage of chlorine is found. An illustration of this has been already given, in testing manganese by means of arsenious acid. The same method is pursued when estimating bleaching powder, except that the preliminary distillation, in order to obtain an oxychloride of potassium, is unnecessary, since the analogous lime salt requires merely to be triturated with tepid water, and the solution is procured at once. There is one thing connected with the testing of bleaching powder which is particularly worthy of note, namely, that in taking a sample, care must be observed that one of an average strength is operated upon. To insure this, a few ounces or less may be gently rubbed together in a dry mortar, and the quantity which is required then weighed out of this. Unless such precaution is taken, the inequality in the strength of portions, even of the same charge, of bleaching powder may give rise to very serious errors.

A test which is frequently applied by bleachers is that introduced by WELTER, and consists in observing to what extent the salt will destroy the color of indigo. One part of best commercial indigo blue is dissolved in nine parts of concentrated sulphuric acid, then diluted to any required point, and the quantity of chlorine required to discharge the color ascertained by a known weight of chlorate of potassa, decomposed by hydrochloric acid—the chlorine thus evolved absorbed by potassa, as in the case of manganese, and this solution added from a graduated test glass to a certain amount of the colored liquor. Sometimes this species of testing is performed in the following manner:- The sample of bleaching powder is weighed and dissolved in a known volume of water, then the standard measure of strongly acidulated solution of indigo poured into it till the color ceases to be destroyed. Unless the operator mixes the tests in a stoppered bottle, a loss of chlorine will result from the action of the strong acid solution upon the lime compound. As a check upon the first determination, a second estimation should be made, in which case the whole of the solution required in the preceding instance should be measured off in a tube graduated from below upwards, and added to within one or two divisions to the bleaching liquor at once, and the whole well agitated. After the greater part of the chlorine has been thus combined, the traces still remaining may be easily absorbed by the residuary portion of the indigo test solution. It is more convenient to add the bleaching solution to the indigo until it loses the color, nevertheless the results are very unsatisfactory.

Indeed, the indigo test, although much used by practical bleachers, is at best a very unsafe one: in the first place, the indigo solution decomposes by long keeping, and consequently loses its color. The products thus obtained are not correctly known to chemists. Further, it makes an important difference when the solution of chlorinated lime is added quickly or slowly. In the former instance, where a momentary excess of chlorine exists at the place of its introduction, the gas is partly evolved and partly enters into combination, probably forming chlorisatin, while by the slow addition of the solution merely chlorisatin results. Lastly, it is difficult to observe the completion of the reaction, as the mixture of the original blue with the yellow of the decomposition products gives rise to a shade of green. —*Schwartz.*

Many other tests besides these are, or may be, used, for ascertaining the value of bleaching powder. Such, for instance, as protochloride of manganese, which affords with the salt a brownish-black precipitate of peroxide; thus—

$$\underbrace{Mn\,Cl}_{\text{Chloride of manganese.}} + \underbrace{Ca\left.\begin{matrix}O\\Cl\end{matrix}\right\}H\,O}_{\text{Bleaching powder.}} = \underbrace{Mn\,O_2}_{\text{Peroxide of manganese.}} + \underbrace{Ca\,Cl}_{\text{Chloride of calcium.}} + \underbrace{H\,Cl}_{\text{Hydrochloric acid.}}$$

But this is rarely resorted to; neither is that course by which the quantity of chlorine is estimated from its reaction in converting ferrocyanide of potassium into ferricyanide, a favorite test among the manufacturers, and hence it would only burden the mind of the reader to give numerical directions for conducting the analysis in this case. The effect produced is, however, readily conceived from the formula:—

$$\underbrace{2\,(K_2\,Cfy)}_{\text{Ferrocyanide of potassium.}} + \underbrace{Cl}_{\text{Chlorine.}} = \underbrace{K_3\,Cfy_2}_{\text{Ferrocyanide of potassium.}} + \underbrace{K\,Cl}_{\text{Chloride of potassium.}}$$

which shows that two equivalents of ferrocyanide of potassium afford one of ferricyanide and one of chloride of potassium.

Another test, and one of some merit, is the subchloride of mercury, $Hg_2\,Cl$, which is converted into the soluble protochloride, $HgCl$, by an equivalent of chlorine, thus:—

$$\underbrace{Hg_2\,Cl}_{\text{Subchloride of mercury.}} + \underbrace{Cl}_{\text{Chlorine.}} = \underbrace{2\,Hg\,Cl}_{\text{Protochloride of mercury.}}$$

A certain weight of subnitrate of mercury is dissolved in water, and the amount of subchloride which it yields determined by precipitating a known volume by hydrochloric acid, collecting the precipitate, drying, and weighing. Having acquired this knowledge, a known volume of the standard mercurial solution is taken at each test and precipitated by hydrochloric acid, the solution of the bleaching powder added cautiously, and the menstruum well stirred with a glass rod, till the operator observes that the solution appears transparent like water. The number of measures of the chlorinated liquor used are then read off, and from these the value of the sample is calculated, by the aid of the standard according to which the test solution had been prepared.

But by far the most simple and accurate in its results is the test by means of sulphate of iron. This metal has two states of oxidation—the lower being termed the protoxide, and the other, the sesquioxide. The former is produced when the metal is dissolved in sulphuric or hydrochloric acid, and the latter when either of these solutions is exposed to the air, or oxygen or chlorine gas is conducted through them, or when the metal is dissolved in nitric acid. It is upon this change that the value of sulphate of iron as a chlorometric reagent depends, and the completion of the oxidation is faithfully registered by ferricyanide of potassium, with which the sesquioxide affords a dingy green liquid, whilst the protoxide or its salts strike a fine deep blue. The reaction in the first case is represented by the formula:—

$$\underbrace{2\,(Fe\,O,\,S\,O_3)}_{\text{Sulphate of iron.}} + \underbrace{H\,O}_{\text{Water.}} + \underbrace{Cl}_{\text{Chlorine.}} = \underbrace{Fe_2\,O_3,\,2\,(S\,O_3)}_{\text{Basic sesquisulphate of iron.}} + \underbrace{H\,Cl}_{\text{Hydrochloric acid.}}$$

According to the wishes of the operator, he can either make the analysis directly, by adding the solution of the protosalt of iron to that of the bleaching powder, observing when the former begins to be in excess by the formation of the blue precipitate alluded to, or he may, contrariwise, pour into the normal solution of iron the bleaching liquor, and ascertain when the blue precipitation ceases. As the solution of the salt of iron is apt to oxidize readily, even in the presence of an acid, it is preferable to employ the sulphate in a crystallized state. For its preparation, fine piano-forte wire is acted upon by sulphuric acid till dissolved, and the latter is nearly neutralized; the liquor is then filtered and set aside to crystallize, being careful to keep it slightly acid, and a few fragments of the wire suspended in it, to prevent oxidation by the hydrogen evolved. In this case the crystals are well-defined oblique, rhombic prisms of moderate size; but if it be desired to obtain them of less form, the slightly acid concentrated hot lie is filtered into strong alcohol, when the salt precipitates in a finely clear pulverulent state. When the crystals are separated from either of these menstrua, and dried between folds of blotting paper, they have the composition expressed by the formula, $FeO,\ SO_3 + 7\ HO$, the equivalent of which is 139. Now it has been shown that two equivalents—278—of this salt, produce one of sesquioxide of iron by the agency of one equivalent—35·5—of chlorine; hence 78 parts of the salt will be sesquioxidized by 10 of chlorine. In testing, therefore, 78 grains of the iron are weighed and dissolved in tepid water acidulated by hydrochloric acid: this forms the normal test solution. A quantity of the sample to be examined, but which contains more than 10 parts of chlorine, is then weighed and ground with a little tepid water in a mortar to a thick cream; this is next poured into the burette, and the mortar rinsed by fresh additions of warm water, which are poured into the graduated glass, like the former, till it is filled up to zero, and the whole well agitated by placing the palm of one hand horizontally on the mouth of the tube, and shaking it vigorously for a few minutes. A hundred grains of the powder may be taken in this analysis, but as it rarely happens that bleaching powder is under twenty per cent. of chlorine, to avoid the precipitate of lime which falls from one hundred grains filling the burette, preference is given to fifty grains. After the agitation and subsidence of the precipitate above mentioned, the clear solution is poured into the prepared test liquor carefully, and the progress of the oxidation tested from time to time, by bringing the end of the stirring rod in contact with drops of a concentrated solution of ferricyanide of potassium, dotted on a white porcelain or glazed slab. When the blue is no longer visible, and the color appears greenish-yellow, the operator reads off the number of measures of the chlorinated liquor used, and from this, by the annexed calculation, he arrives at the value of the article.

If the oxidation of the iron required fifty-five measures of the liquid, these consequently contained ten grains of chlorine, and the hundred measures of the solution —equivalent to fifty grains of the sample—contained 18·18 grains; and if this be doubled, the value of a hundred grains of the sample will be found to be 36·36 of chlorine. To make this calculation more simple, let it be assumed that the number of measures on the burette be doubled for one hundred grains, that is, 100 × 2 = 200 measures; then

$$55 : 10 :: 200 : 36{\cdot}36 \text{ per cent.};$$

so that in all cases the number of degrees required to oxidize the iron, divided into 2000 = 200 × 10, will give the per centage of chlorine.

The manufacture of chloride of lime has of late become very extensive, the produce of last year being more than treble that of 1844. The quantity now fabricated is from fifteen to sixteen thousand tons annually.

The principal factories in England and Wales, are those of Messrs. JAMES MUSPRATT and SONS, of Liverpool and Flint; and in Scotland, Messrs. TENNANT and COMPANY, Glasgow, are the largest makers.

BONE.—*Os*, French; *Knochen*, German; *Os*, Latin. —The various parts of the skeleton, or the solid framework supporting and protecting the softer portions of the body of animals of the superior orders, are termed bones. They are invested with a membrane called the *periosteum*, which is composed of a thick tissue affording glue, convertible into jelly by boiling with water.

Bones are not equally solid throughout, but present to view on the surface an osseous mass of a more compact nature, while the interior appears as a cavity divided into minute cellules by bony partitions. The cartilaginous portion is formed before the deposition of the earthy substance occurs, and the ossification always proceeds from certain fixed points. According to HORNER, the method of combination of the organic with the earthy matter is not properly understood, but it is generally believed to be by the minute cavities of the bone receiving earthy particles, similar to the pores of a sponge attracting and retaining moisture.

The organic part of the bones may be obtained in a separate state, by immersing them in dilute hydrochloric acid, at a temperature of 53° or 54°. The earthy portion is dissolved by the acid, and a kind of skeleton remains in the form of a cartilaginous substance, transparent, flexible, and elastic, which, when dried, exactly resembles horn. By boiling in water, it is totally converted into gelatin, with the exception of a few fibres, derived from the fine blood-vessels, which are insoluble, and may be separated by filtration.

The inorganic or earthy portion of bone consists mainly of phosphate and carbonate of lime in various proportions, changeable in different animals, and mixed with small quantities, equally fluctuating, of phosphate of magnesia and fluoride of calcium. Bone ash—the earthy salts of bones—is best obtained by calcining the bones; but there are substances then present which did not antecedently exist in them—as, for example, sulphate of soda, formed from sulphur in the cartilage—there are also some alkaline carbonates derived from the same source. The carbonate of lime of the bone loses most of its acid at a white heat.

The phosphoric acid is supposed by many to be somewhat singularly combined; namely, as a basic phosphate, $8\,\mathrm{Ca\,O} + 3\,\mathrm{P\,O_5}$; the Editor, however, looks upon its composition in the same light as any other of the phosphates; *id est*, by assuming an equivalent of water to be present, the salt is an ordinary tribasic phosphate, as under:—

$$\begin{array}{l} 3\,\mathrm{Ca\,O,\,P\,O_5} \\ 3\,\mathrm{Ca\,O,\,P\,O_5} \\ \left.\begin{array}{r}2\,\mathrm{Ca\,O}\\ \mathrm{H\,O}\end{array}\right\}\mathrm{P\,O_5} \\ \hline 8\,\mathrm{Ca\,O,\,H\,O,\,3\,P\,O_5} \end{array}$$

Bone is employed to a large extent in the manufacture of combs, and the handles of the more common kinds of cutlery. The gelatin contained in bones is extracted by boiling: the resulting paste, termed ***size***, is used by dyers and finishers of fustians and velveteens. The bones collected in this country are, for this purpose, considered of greater value, and are said to contain more gelatin than those imported. Recently, bones have been successfully used in a sulphated state—that is, after treatment with concentrated sulphuric acid—as an artificial manure.

The quantity annually imported for the last few years was in—

1850,...........................	27,198 tons.
1851,...........................	31,956 "

BONE BLACK—ANIMAL CHARCOAL.—*Noir d'os*, French; *Knochenschwartz*, German.—Animal charcoal scarcely differs in appearance, or in regard to its physical or chemical properties, from vegetal charcoal; in many particulars, nevertheless, they are far from resembling each other. As the latter almost always retains hydrogen, so the former obstinately keeps a certain quantity of nitrogen, which is very difficult to remove entirely, and can only be expelled at a red heat.

PROPERTIES.—Bone black possesses the singular property of completely absorbing the color of almost any vegetal or animal solution, and of rendering quite limpid and colorless the water charged with it. Vegetal charcoal shares this property with it in a certain degree, but does not possess the same energy.

The first observations on this subject were made by LÖWITZ, at the close of the last century. He observed with care the decolorizing properties of vegetal charcoal, and endeavored to make some applications of it. From 1800 to 1811 it was extensively used for depriving crude sirups of color; but at the latter date, M. FIGUIER, an apothecary of Montpellier, showed that the same effect was produced by animal charcoal, not only in a better manner, but also more speedily and certainly. The discovery was promptly applied to the refining of sugar, and now forms one of the most essential processes of that art.

In using animal charcoal for depriving a liquid of its color, the operation is more successful when the latter is slightly acid or neutral, than when it is alkaline. Occasionally, alkaline menstrua, instead of losing their primitive tint, have even acquired additional color. This effect is due to the presence of a brown matter, soluble in alkali, which is always met with in organic charcoal, when it has not been exposed to a sufficiently intense heat; it much resembles *ulmin*, and does not, perhaps, materially differ from it. This remark, however, may admit of exceptions; and, indeed, it is allowed that solutions of sugar are better deprived of their color when alkaline, than when acid.

The action of animal charcoal on colored liquids is usually accelerated by heat. In most cases, the liquor to be deprived of color is brought to a state of ebullition, the charcoal is thrown in, the mixture agitated for some moments, and then filtered. If the boiling be prolonged, it frequently happens that a portion of the coloring matter which was at first precipitated or imbibed by the charcoal is redissolved; so that, by using even a larger quantity of charcoal, the decoloration is less complete, if the time which is strictly necessary be exceeded.

It is difficult to account, in a satisfactory manner, for the decolorizing power which carbon possesses. The universality or generality of the effect produced on a multitude of organic substances, each different in appearance, would seem to indicate that it depends on some cause purely mechanical or physical. But the following experiment, due to M. BUSSY, shows that the reaction is strongly influenced by ordinary chemical forces, if it be not entirely attributable to them. If a solution of indigo in concentrated sulphuric acid be diluted with water, and animal charcoal added in sufficient quantity, the solution will soon be deprived of color. If now the charcoal is repeatedly washed with water, not the slightest trace of sulphate of indigo can be extracted; the washings will contain only free sulphuric acid. If, on the contrary, the charcoal be treated with a solution of potassa, soda, or ammonia, sulphate of indigo will separate from the charcoal at once, and the liquor, on filtration, will show the previous blue tint. In this, and indeed in almost every case in which it produces the characteristic result, the animal charcoal appears to perform the part of a weak base, and combines with the coloring matter, receiving an augmentation of weight. It has, indeed, been ascertained that most coloring matters also present the characteristics of weak acids.

Whatever opinions may be formed with reference to the action of animal charcoal in decoloring liquids, there are some facts observed by M. BUSSY, which may contribute to throw light on this subject, and which it is proper here to record. Animal charcoal is almost always prepared from the bones of the ox, the sheep, or the horse. It contains, therefore, the salts of lime, which enter into the composition of these bones; and consists of about ten per cent. of nitrogenized charcoal, two of carbide or silicide of iron, and eighty-eight of phosphate or carbonate of lime, mixed with a little sulphide of calcium, or of iron. Now, if 100 represents the decolorizing effects of 100 parts of this animal charcoal, and the 10 parts of pure charcoal which these contain be then taken, it will be found that their decoloring power will only be 30 when brought to a comparative trial. On the other hand, it will be discovered, by similar trials, that the phosphate of lime of the bones, as well as the carbonate of lime, have not the property of decolorizing liquids; from which it appears that 100 parts of pure charcoal, which represent 1000 of crude charcoal in regard to chemical composition, represent not more than 300 in decolorizing effect, a circumstance never yet accounted for.

The animal charcoal of commerce, owing to its bad preparation, is subject to great variation in quality. When either over or under calcined, it is less energetic; in the former case, because it is less porous; in the latter, because the animal matter, not being quite consumed, makes a kind of *varnish* in the charcoal which prevents its acting. The best of all is that which has been calcined to the exact point of destroying the animal matter, but *not further*.

The state of division in which charcoal exists, is a most essential point for consideration. Thus, the charcoal obtained by calcining a mixture of potassa and animal matter in the manufacture of prussian blue, and which remains after the lixiviation of the residues, possesses the decoloring property to a degree which ordinary bone-charcoal never attains. In reality, this charcoal is pure, but its decoloring power is ten times more energetic than that of crude bone black, and consequently three times greater than that of the purified article. This difference may arise from the state of division, which, in the prussian blue charcoal, is obtained by a chemical segregation of the particles, and in the other by mechanical means; the former being, so to speak, reduced to a molecular state, while the latter is far removed from such a condition. But it would appear, likewise, that the difference is partly attributable to the fact, that the charcoal calcined with potassa has had its nitrogen disengaged from it by this base, and is, on that account, better carbonized.

The state of division, nevertheless, appears to be the essential condition from which the properties of animal charcoal are derived. In fact, the charcoal proceeding from pure organic matter has little decoloring power. That which is mixed, on the contrary, with abundance of earthy matter, decolorizes tolerably well, and that which has been formed in the midst of fusible saline substances still better. In the first kind, the molecules collect into masses; such charcoal, moreover, is of a lustrous nature, and presents plates distinctly continuous. In the second, the molecules can only approximate imperfectly to each other, because of the earthy substances which keep them apart. In the third, the same effect is produced, but in a higher degree, on account of the continual movement of the mass during carbonization. Charcoal of the second and third classes is always of a dull color, which implies that it exists in a very minute state of division. BUSSY and PAYEN have shown that they took from some, and imparted to others, the decoloring property, according as they rendered them *lustrous* or *dull*, by suitable modifications in the process of carbonization. It has long been known that charcoal from blood has only feeble decoloring powers, while that from blood and potassa has the best possible effect. The former is brilliant; the latter, dull. Bone-charcoal which is dull, decolors moderately well; but it has little energy if the bones have been carbonized with a mass of gelatin, which leaves a deposit on it, causing it to become brilliant. At the same time one must not forget the fact, that the potassa is not limited to mechanical action. In seizing on the nitrogen to form cyanide of potassium, it may increase tenfold the decoloring power of bone-charcoal, as has been fully proved. A precise idea of all the effects of animal charcoal, may be obtained by perusing the following table of the decoloring power of different varieties of charcoal, by M. BUSSY:—

Species of charcoal.	Weight.	Indigo test consumed	Molasses test consumed.	Blanching by indigo.	Power by molasses.
	gramme.	litres.			
Blood calcined with potassa,	1	1·60	0·18	50	20
Blood calcined with chalk,	1	0·57	0·10	18	11
Blood calcined with phosphate of lime,	1	0·38	0·09	12	10
Gelatin calcined with potassa,	1	1·15	0·14	36	15·5
Albumen calcined with potassa,	1	1·08	0·14	34	15·5
Starch calcined with potassa,	1	0·34	0·08	10·6	8·8
Charcoal from acetate of potassa,	1	0·18	0·04	5·6	4·4
Charcoal from carbonate of soda by phosphorus,	1	0·38	0·08	12	8·8
Calcined lamp-black,	1	0·128	0·03	4	3·3
Lamp-black calcined with potassa,	1	0·55	0·09	15·2	10·6
Bone black treated with hydrochloric acid and potassa,	1	1·45	0·18	45	20
Bone black treated with hydrochloric acid,	1	0·06	0·015	1·87	1·6
Oil calcined with phosphate of lime,	1	0·064	0·017	2	1·9
Crude bone black,	1	0·032	0·009	1	1

The first and most striking fact seen on referring to the table is, that the relative decoloring powers as measured by indigo or molasses are far from being identical. The author of the table remarks, on this subject, that the more charcoal a substance requires for its decoloration, the more does the decoloring power of the perfect charcoal tend to diminish, as compared with the ordinary bone-charcoal taken for the unit measure of this energy, in all cases.

A result not less evident is, that the blanching power is inherent in the pure carbon, since that which is obtained from the decomposition of carbonate of soda possesses it in a high degree. Moreover, although all the facts relative to the decoloring power of animal charcoal have been here brought together, this property must be considered as common to every kind of charcoal, provided it exists in as minute a state of division as that in which bone black is always found.

In recapitulation, it will be seen from what has just been stated, firstly, that the decoloring property is due to the charcoal; secondly, that it is modified, nevertheless, by the presence of earthy salts; thirdly, that the charcoal acts by combining with the coloring matter; fourthly, that this combination is effected according to the fine division of the particles of the charcoal, denoted by a dull appearance; fifthly, that this state may be communicated to it by a suitable mixture of mineral matters, particularly of potassa, during carbonization, provided they are supplied in sufficient quantity to prevent the charcoal from agglomerating.

It was formerly the general opinion, and appearances seemed to corroborate it, that the action of animal charcoal was only exerted upon bodies of organic origin, particularly coloring principles, bitter and aromatic substances, as turmeric, litmus, indigo, sugar, sirups, *et cetera.*

GRAHAM has since found, however, that inorganic matters were equally influenced, and it has been proved that charcoal abstracts the lime from lime-water, and completely absorbs the metallic oxides, particularly those of lead, as also ammonia and potassa, from their aqueous solutions. According to experiments conducted by CHEVALLIER, neutral acetate and nitrate of lead are entirely taken up by bone charcoal, whether it is in a washed or unwashed state. The former is more readily absorbed than the latter. The absorption requires—with from one to ten parts of charcoal to one of the salt—from one or two to six days at the ordinary temperature, but at a boiling heat from two to five minutes only.

Whether the lead salt was dissolved in water, alcohol, or acetic acid, it was equally taken up, but from a hydrochloric or nitric acid solution it was never completely removed.

Through its agency, says GRAHAM, even the iodine is separated from iodide of potassium. The investigation of WEPPEN appeared to prove that the action of the charcoal extended to all metallic salts; with the following, no doubt remains of this being the case, *videlicet*: the sulphates of copper, zinc, chromium, and protoxide of iron, nitrates of nickel, silver, cobalt, suboxide, and oxide of mercury, acetate of lead, tartrate of antimony, and potassa, protochloride of tin, protochloride of mercury, and acetate of the sesquioxide of iron. In the separation of these salts by charcoal, three cases may occur: the salt is either absorbed unchanged, or a basic compound is precipitated upon the charcoal, or the oxide in the salt is reduced to the metallic state. Some metallic acids, as antimonic and tungstic, are thrown down from their potassa or ammonia salts, although no effect is produced on arsenite or arseniate of soda. The salts containing alkali as base are little affected. Free acids either hinder or entirely prevent the precipitation of the metallic oxides.

When defecated saccharine juice is operated upon, different substances—such as sugar, gum, mucus, and other organic matters, salts of lime and the alkalies, besides caustic lime—are simultaneously brought into contact with the charcoal; pure water is the first product that passes through, but a considerably larger quantity is obtained than was employed for moistening the charcoal. Water is then obtained of a decidedly saline character, which increases in strength; and after this has percolated for a short time, a sweet taste becomes perceptible, which gradually increases, and at last entirely masks the saline. This sweet fluid at length begins to acquire an alkaline reaction, which rapidly increases in intensity. Some time afterwards a slight coloring of the filtrate may be observed, and finally the liquid is as dark as when thrown upon the filter, and then the action of the bone black entirely ceases.

These phenomena may be easily explained. They prove that the attraction for the saline ingredients ceases sooner than that which it possesses for coloring matters, but that the absorbent action is primarily exerted upon each component of the liquid.

The inference drawn by **LÜDERSDORF**, that the charcoal relinquishes one class of absorbed substances for others, to which it shows a preference, seems unfounded.

The absorption of lime by charcoal has been more intimately studied by **SCHATTEN**. He ascertained that caustic lime, whether dissolved in water or in saccharine juice, was taken up. The power of absorption for lime is affected by many circumstances. A temperature of 167° Fahr. increases it in the proportion of three to four. Time, also, causes variation; under similar circumstances, only twice as much is abstracted in twenty-four hours as in half an hour. When double the quantity of lime water is acted upon by the same amount of charcoal, one and a half times as much lime will be absorbed in the same period. On a quantity of charcoal being taken and treated repeatedly with lime water, and washed and dried between each operation, the absorption diminished in proportion as the charcoal became saturated with the alkaline earth. Thus one hundred parts of bone charcoal, during the first treatment with beet-root juice, absorbed 1·63 parts; in the eleventh process 0·51, or 3·2 times less; the total amount taken up during the eleven operations was 6·26 parts.

Bone charcoal, containing five per cent. of lime, combined with phosphoric acid, absorbed twice as much lime as that which had nine per cent.—*Knapp.*

PREPARATION.—The preparation of animal charcoal is conducted in different ways; by one method the bones are calcined in small pots closely packed up in a kiln. On this plan, the bones, broken into small fragments, are placed in small cast-iron vessels of the form shown in Fig. 207, about three-eighths of an inch in thickness, two of which, after filling, are dexterously placed with their mouths in contact, and then luted together with loam. The lip of the upper is made to fit inside that of the lower one. These double vessels, a pair of which contain about fifty pounds of bones, are arranged in parallel rows, and also upon each other, in an oven, till it be filled. This oven, or kiln, may be either oblong or upright. The latter is represented by Figs. 208, 209, and 210. A is the fireplace, or grate, for the fuel; C C are apertures in the dome of the furnace for the admission of flame; the divisions of these orifices are shown in Fig. 208; B is the wall of brickwork; D is the space where the pots are placed; E is the door by which the workmen carry in the vessels, and which, before the carbonization commences, is built up with firebricks, and plastered over with loam; F F are flues for carrying off the disengaged gases into the chimney, G.

Fig. 207.

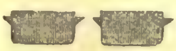


Fig. 208.

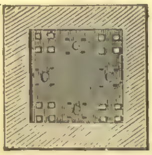


Fig. 209.

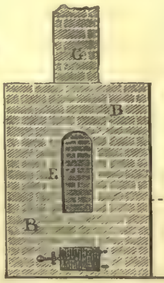


Fig. 210.

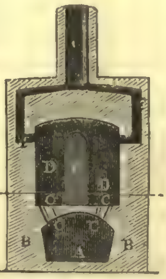


Fig. 211 is a longitudinal section, and Fig. 212 a ground plan of a horizontal kiln for calcining bones. A is the fire-chamber, on a level with the sole of the oven; it is separated from the calcining hearth, C, by a pillar, B. In this pillar, or wall, several rows of holes, D, are left at different elevations; E is the entrance door; F F are the outlet vents for the vapor, smoke, and gases into the chimney, G; a sliding damper plate, for regulating the admission of air into the fire in the space, A, is denoted by H.

Fig. 211.

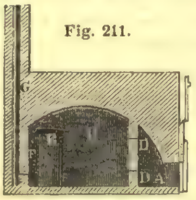
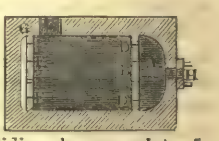


Fig. 212.



The offensive emanations are, by this arrangement, partly consumed, and partly carried off with the smoke. For the complete destruction of the smell, the vapors, *et cetera*, should pass through a small furnace, or be otherwise submitted to combustion.

In both the kilns represented, the interior walls are built of firebricks. In the oblong one, the heat is greatest near the vaulted roof; in the upright one, near the sole; the pots containing the larger lumps of bones should be accordingly placed. The former oven is generally constructed to contain from one hundred to one hundred and fifty, and the latter about seventy pots; the dimensions may, however, be varied at pleasure.

After the pots have been properly packed into the oven, and the entrance door is closed, the fire is at first gently applied, but is afterwards raised and maintained at a brisk heat for eight or ten hours. The draught is now moderated by the door of the ash-pit, and the damper being nearly closed, a steady ignition is kept up for an additional six or eight hours without fresh firing, after which time the doors are opened to cool the furnace. After this has been effected, the brickwork which closed the entrance is taken down, and the kiln is emptied, but is immediately filled again with a fresh set of vessels previously prepared. The pots just withdrawn are, after a short period, opened, and the contents put into the magazine.

When the preparation of bone black is connected with that of ammoniacal salts, the carbonization is performed in cylinders of cast-iron, terminated at one extremity by a pipe of three inches diameter, which conducts the evolved gases into a long series of refrigerating apparatus. The other end is opened or closed at will, by means of a movable disc of the same metal. These cylinders are placed horizontally in a furnace. They are filled with crushed bones, previously deprived of their fatty matter, and the disc being closed and luted, the temperature is raised to a red heat, and maintained at that point for thirty-six hours; at the end of which time the lid is opened, the residue withdrawn, and enclosed in metal receivers or boxes, to be extinguished while the cylinders are recharged.

Bone black thus prepared requires reducing to a finer state of division. For this purpose it is first crushed to a coarse powder, and the process is concluded by passing it between stones, similar to those used for grinding corn, but it may be pulverized between steel cylinders, and in many other ways. It is generally damped during grinding, to allay the dust which would otherwise arise.

If it is not desirable to collect the other products of the distillation of the bones, the pipe which allows their escape may be immediately carried under the fire-grate, where combustion will ensue, thus not only avoiding their disagreeable odor, but also economizing fuel.

Bone black is sometimes employed as a color; and as in this case it requires to be more thoroughly divided, it is made with water into a liquid paste, which is put into *a color-mill*, and brayed the necessary time; the resulting mass is then put into earthen moulds, and left to dry.

Ivory-black is obtained by analogous processes. The manufacture of animal charcoal is best when established in the neighborhood of populous cities or towns, as the bones used for the purpose generally proceed from butcher meat, and are collected in the streets and otherwise.

REVIVIFICATION.—It is natural to inquire whether the animal charcoal which has been employed for decolorizing sirups, could be prepared so as to effect it a second time. The facts already stated show that this could not be done by mere calcination.

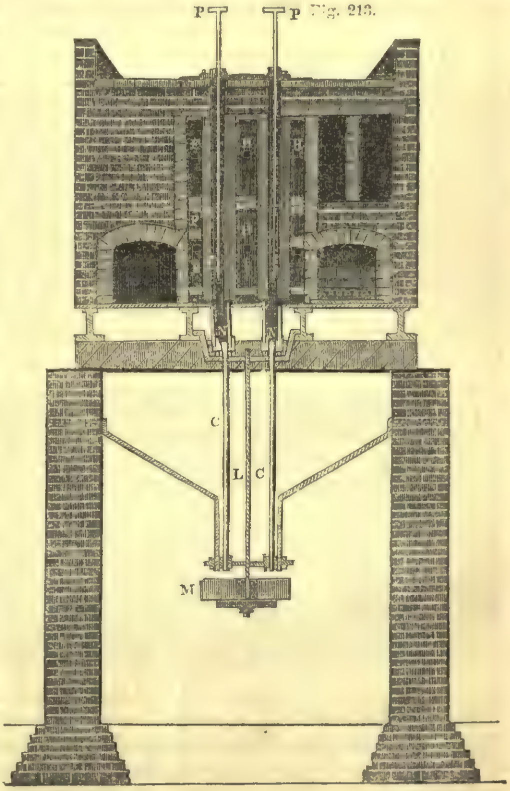
Abroad, the renovation of the charcoal, with some slight modifications in the methods of carrying it out, consists in submitting it to fermentation, washing—in some cases with hydrochloric acid, and afterwards with water; in others, with the latter only—drying, and finally heating to redness.

During this second burning, the requisite degree of heat is much lower than that originally required; consequently, the operation is effected without pots, and the danger of burning the charcoal to ash is proportionally diminished. In France, the process is conducted in reverberatory furnaces, having a flat-arched roof, and the doors made very close. In Magdeburg, narrow cylinders, fitted at the top with a lid, and below with a sliding door, are used, several of which are placed upright in a reverberatory furnace.

The fermentation of the charcoal previous to burning offers considerable advantage, as the greater portion of the absorbed organic matters is decomposed and evolved as gas, leaving only a small quantity in the pores to be charred. On the other hand, however, it converts any lime which may have been taken up, into carbonate, and renders its removal more difficult; although the acetous fermentation may ensue, or even when hydrochloric acid is employed for washing, the action of the acids is restricted to the surface, while the interior of the pores is still charged with carbonic acid.

One of the best methods is that proposed by SCHATTEN, and carried out at Magdeburg. As the charcoal leaves the filters, and before the lime has had opportunity for absorbing carbonic acid, it is completely saturated with dilute hydrochloric acid, which immediately acts very energetically, and causes evolution of much heat. The charcoal is then placed in large reservoirs, and water, mixed with about half a per cent. of hydrochloric acid, poured upon it. This treatment occasions a lively fermentation, which extends over about eight days, when the water, which has become thoroughly impregnated, is removed, and another quantity of fresh supplied. After this has been repeated several times, the charcoal is treated with water, again containing acid, in smaller vessels, until the lime is completely saturated, when it is again washed, and then heated to redness. Any large excess of acid must be carefully avoided, as it would attack the phosphate of lime, soften the charcoal, and render it useless. The upper layers of bone-black in the filters which first come into contact with the saccharine juice, hold six times as much lime as those below.

Fig. 213.

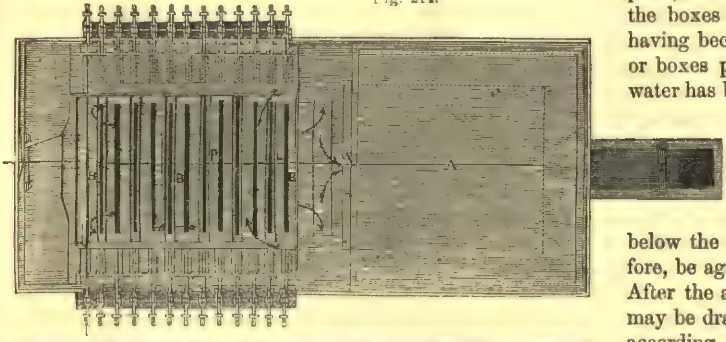


The decolorizing power of charcoal once used, is said to be completely restored by treatment with steam at a very high temperature, but the statements relative to this mode of procedure require more confirmation. It is apparent that the process cannot occasion any loss, but it is equally obvious that the lime will not, by this means, be removed.

Fig. 213 is a sketch of the charcoal re-burner, patented some years ago by Parker, and now used by many of the London charcoal-makers.

Narrow spaces constructed of firebrick, the bottoms of which are indicated in the engraving at N, are surrounded by the flames from a fire passing up the flues, B, F, and H, which retain them at a low red heat. These narrow upright brick retorts are connected below, so as to be air-tight, with the still narrower sheet-iron receivers or coolers, C C, into which a certain quantity of the re-burnt charcoal can be allowed to fall at short intervals, and cool without access of air. It is ultimately removed underneath, passing through the measurer, M. The re-burners are open at the top, where the charcoal is admitted and piled up in a heap above the aperture, so that, as one portion is removed below, its place is immediately occupied by a quantity falling down from above. P P are tubes through which the temperature in the interior of the charcoal can be observed, and which also serve as an exit for the gases evolved in the lower part of the re-burners.

Fig. 214.



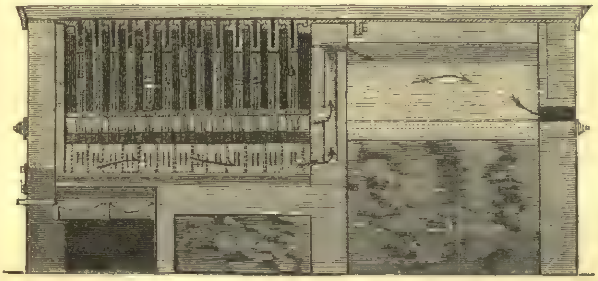
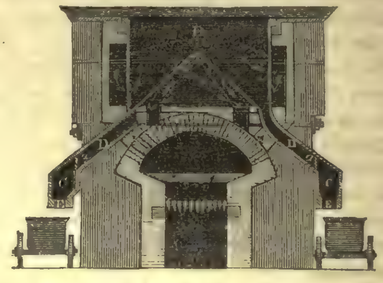


Fig. 215.

Figs. 214, 215, and 216, represent the apparatus of Messrs. Pontifex and Wood—the first being a plan, the second a longitudinal, and the third a transverse section.

The charcoal that has been used in the filters, after having been washed in a cistern, is taken out and laid aside to allow the water to drain from it; it should then be removed to the re-burner, and placed on the wrought-iron plate, A, which forms the back part of the top; the fire having been lighted, the plate will become hot, and thoroughly dry the charcoal before the retorts, B B B, B B B, are heated. When it has become perfectly free from moisture, it should be raked forward into the retorts, filling them up, and heaping the charcoal over them to the height of six inches or more. After the retorts are thus charged, a red heat is applied for fifteen or twenty minutes, after which the operation is finished.

Fig. 216.



The slides, *a*, in the boxes, C C—Fig. 216—are then opened, which allows the charcoal contained in the pipes, D, and a portion of that in the retorts, to run into C C; the slides are subsequently closed, the charcoal descends, and the hollows produced in the heap over the retorts are supplied from the charcoal on the plate, A. The slides, E E, at the bottom of the boxes are now opened, and the charcoal having become tolerably cool is run into trucks or boxes placed below C C, when, after a little water has been thrown on it to reduce the temperature still further, it may be stowed away, ready for use. The first charge is never properly burned, a portion having been left in the pipes, D, which are below the heat of the fire; this must, therefore, be again thrown on the top of the retorts After the apparatus is once at work, a charge may be drawn every fifteen or twenty minutes, according to the temperature, which may be regulated by the damper, F.

The fire in this arrangement should never be put out, as the cooling of the retorts soon destroys them. They may be worked at any velocity, by allowing a greater or less draught, but the charcoal must never be permitted to become red-hot above the tops of the retorts, where it is in contact with the air. If the charcoal is properly heaped up over the retorts, and the charge drawn regularly, the apparatus works admirably.

The receptacle, C, into which the charcoal is let down when it is sufficiently burnt, is divided into as many compartments as there are retorts, each holding half the quantity burnt in one of them, the corresponding receptacles on the other side of the apparatus having the remainder. The valves, *a*, are flat plates of cast-iron working in grooves, and are intended to open or close the communication between the retorts and the receptacles. They are worked by the handles abutting on each side of the plan. Messrs. Pontifex originally constructed this valve of a flat plate of wrought-iron, reaching to the end of the set of retorts, with alternate perforations to fit their bottoms, so that, by drawing it out three or four inches the communications of the latter with the receptacles were simultaneously opened; but it was found that so long a plate of thin iron was liable to warp with the heat, and, therefore, separate valves for each retort were substituted. This long perforated slide is, however, used for letting the charcoal out of the receptacles into the trucks for conveying it away, as the heat is not sufficiently intense to cause the valve to warp.

In the longitudinal section of the re-burner, a section is shown of the whole of the retorts cut across in the middle, on the line of the union of the two legs; and consequently it shows the end-sides of the retorts slanting towards these legs, or *breechings*, as they are termed.

The transverse section shows the retorts cut across the middle, at right angles to the longitudinal section.

The direction of the flues is shown by the arrows on the drawings. Each retort revivifies fifty pounds of charcoal every fifteen or twenty minutes, and, consequently, the burner revivifies about nine and a half hundredweight, at least, of spent charcoal per hour.

PURIFICATION.—Animal charcoal is never purified for the requirements of the arts, but in the laboratory this must often be done, to prevent the introduction of calcareous matter into the solutions to be decolored.

This depuration is performed by putting the charcoal into an earthen vessel, sprinkling over it a small quantity of water, and adding, gradually, ordinary hydrochloric acid. When the effervescence occasioned by the carbonate of lime has ceased, it is ascertained that the liquid is quite acid, and the whole is left to digest for twenty-four hours. It is then diluted with water, the charcoal is thrown upon a cloth, and washed with boiling water, to which is added one-tenth of hydrochloric acid. These effusions are continued so long as the acidulated water gives a white precipitate on the addition of ammonia. When it ceases to produce this effect, the operator is assured that all the phosphate of lime is removed, and distilled water is substituted for the acidulated, continuing this new washing till blue litmus paper is no longer reddened by the percolating liquid. The remaining charcoal is pure, and may serve as a standard by which to estimate the decoloring power of the charcoal of commerce, and to fix its price, remembering that one part of the former ought to represent three times its weight of the latter.

It is obvious that the fabrication of animal charcoal is limited by the nature of things, and as new outlets are found for the products in connection with which it is employed, the facture will be more fully developed.

ANIMAL BLACK AS A MANURE.—One important application of this substance is as a fertilizing agent. The properties of soot as a manure have been long known; and the action of animal black is similar, but its value has often been underrated from ignorance of the manner of its operation, and of the particular kind of soils on which, and on which alone, it produces a beneficial effect. The residuary animal black of the refineries is largely applied in France for this purpose; and the following important details on the subject embrace the results of M. A. DE ROMANET's investigations, explaining clearly, on strictly scientific principles, the theory of its mode of action on vegetation.

Firstly: The black of the refineries produces no sensible effect on old soils, that is to say, on lands that have been long under cultivation. It is evident, therefore, that it does not contain within itself all the constituent elements of the alimentary plants. The theory of its failure in such soils is thus explained:—The vegetal remains which are found so abundantly in newly reclaimed lands, do not exist in soils that have been worn out or exhausted. Hence it is farmyard manure which agrees with the latter, because, being chiefly composed of the straw of grain, and a quantity of animal droppings, it presents, in a more complete although less energetic form, the elements essential to the nourishment of cereals, and of almost all economical plants.

Secondly. If, when animal black is employed for manure, the same cereal may be sown in a new soil for several years in succession, without observing any diminution in the produce, it is because this soil contains a superabundant quantity of eminently fertilizing vegetal worn-out matter, and because it is sufficient for obtaining good crops, to supply it with ingredients of a different nature in which it is wanting, and which the cereals require.

Thirdly: These new soils would yield abundant returns with common manure, and without the co-operation of animal black, if one merely allowed sufficient time to elapse, after clearing and ploughing up the ground, to permit the atmospheric air to deposit in the soil certain nutritive elements indispensable to the vegetation of the alimentary plants. Therefore, by furnishing instantaneously to this *incomplete* though rich soil the matters which it does not yet possess, the black only anticipates and hastens the slow and regular action of the meteorological agents of which the air is the vehicle, especially the action of the rains, which incessantly convey ammonia into the soil, but do so slowly and sparingly, whereas the albumen of the blood which the refinery black contains, disengages ammonia in great abundance, by being decomposed in the soil.

Fourthly: Animal black enables the agriculturist to obtain cereals in those new or heathy soils, which, without its co-operation, produce only, when first reclaimed, heaths, sedges, reeds, and other plants little adapted for the food of animals. To render such soils fit to produce good cereal crops, it is sufficient that, along with the common manures, they receive one, or at most two, applications of animal black. The black, therefore, neutralizes certain principles with which these kinds of soils are impregnated—soils which, from time immemorial, have been characterized by agriculturists as *sour* or *bitter*. The principles thus neutralized are powerful antiseptic or conservative agents, analogous to tannin, or tannic acid—principles as hurtful to the cultivation of alimentary plants as they are favorable to the vegetation of reeds, heaths, and other plants of that description.

Fifthly: If, in certain cases, the phosphates contained in bone black neutralize the acids which abound in the soil of heath, this effect is produced by their combining with the acids, which render them soluble in water, and hence easily assimilated.

The sum of M. DE ROMANET's deductions amounts to this:—1. That the residuary animal black of the refineries produces no sensible effect on old soils, because they are exhausted of vegetal *humus*, which it has not, like farmyard manure, the power of restoring, since it contains none itself. 2. With respect to heathy or newly-reclaimed lands, the animal black completes or supplements the principles—eminently fertilizing indeed, but of vegetal nature only—which the soil of heath contains, by furnishing to it, in a rapidly assimilable form, the elements required for alimentary plants in which it is wanting, and especially the nitrogen disengaged in the form of ammonia by the albumen of the blood. 3. It accelerates and greatly assists the regular, but slow and limited, action of the air, rain, and other meteorological agents. 4. It instantaneously neutralizes the bitter and acid principles of heathy soils—principles at one and the same time hostile to the culture of alimentary plants, and favorable to the vegetation of plants unfit for the nourishment of animals. 5. Lastly, the phosphates contained in the bone black, combining with the acids diffused in the soil of heaths that are not marly, become, in consequence of this combination, soluble in water, and hence furnish abundantly to cereals the quantities of phosphoric acid which these plants cannot dispense with.

SUBSTITUTES FOR BONE CHARCOAL.—Of the substitutes which have been proposed for bone charcoal—none of which, however, are of equal power—the best hinherto known is that obtained from bituminous shale. This mineral is constituted, like bone, of an earthy and an organic constituent, and yields a similar charcoal. The rare occurrence of the substance places it beyond the reach of most manufacturers, and the capability of its decolorizing properties being restored by the aid of hydrochloric acid is very questionable.

Another substitute is known under the name of *carbon*, and is obtained by charring molasses. The large quantity of salts, particularly those of the alkalies, which must be relatively increased in the charcoal so obtained, are not in favor of the efficacy of this substance.

New Decolorizing Agent for Sirups.—Whilst this work is passing through the press, a correspondent of the *Journal Polytechnique de Dingler* announces the successful application of peat charcoal to the decolorization of sirups. He states that while engaged in experiments on the products of the distillation of peat, he was struck with the physical character of the charcoal, and its resemblance to animal black, from which he conceived the idea of trying its decoloring properties. It evidently does not result from the fact that the charcoal of peat or turf is known to operate as a disinfectant, that it should possess the property of attracting vegetal and animal coloring matters, since wood charcoal, for example, which is nearly equal to animal black in disinfecting power, has very little decoloring action. The French experimentalist states, however, that having reduced the peat charcoal to powder, and washed it with pure water, he found that it exercised an almost immediate effect in decoloring port wine, infusions of cochineal, campeachy wood, and other analogous substances. The same effect was produced on sirups, from which he procured, by evaporation, a sugar remarkably white. He affirms that five parts of peat charcoal exercise as much decoloring effect as four parts of animal black. This result, if confirmed by further experiment is highly important in a practical view, for peat charcoal may be easily produced at a fraction of the price of bone black. Its decolorizing action is attributed by the discoverer to its great porosity, resulting from the earthy matters which the charcoal contains in the proportion of 8 to 12 per cent., and which are presumed to disperse and isolate the charry particles from one another, thereby exposing the entire surface of each to exert that peculiar attraction on which the decoloring effect depends. The editor cannot from his own experience attest the efficiency of the charcoal of peat as a substitute for bone black; but those who may feel disposed to put it to the test of experiment, must not forget that peat contains in its composition both iron and sulphate of lime. Before using it in sugar-refineries it ought, therefore, to be carefully washed with hydrochloric acid, to extract the protoxide of iron and the alkaline bases. These last communicate a yellow color to sirups; and, during the evaporation, the protoxide of iron changes into peroxide, which tinges the sirup and the sugar of a reddish colour.

BORACIC ACID. — *Acide boracique*, French; *borsaüre*, German; *acidum boracis*, Latin; *sal sedativum*, HOMBERGII.—This acid is the only compound of borium and oxygen, and was first obtained by HOMBERG in 1702. It is prepared in the pure state by dissolving forty parts of biborate of soda—borax—in one hundred parts of boiling water, and adding twenty-five parts of hydrochloric acid to the hot solution. The boracic acid deposits as the liquor cools; collect it on a filter, wash it once or twice with cold water, allow it to drain. redissolve it in a little hot water, and recrystallize; wash the crystals with a little cold water, and press them between folds of bibulous paper. The mother liquor and the washings may be evaporated to afford a further quantity of the acid. The boracic acid, when dry, will still retain a trace of free hydrochloric acid, which may be driven off with a part of the water of crystallization, by heating to a temperature of about 234° Fahr. The usual method consists in decomposing borax with sulphuric acid; but the boracic acid thus obtained is always contaminated with a certain portion of the sulphuric acid, which is very difficultly dissipated.

The crystallized hydrate of boracic acid is soluble in about thirty parts of cold and three of boiling water; the latter solution deposits it in pearly scales as it cools; it also dissolves in alcohol, to the flame of which it communicates a beautiful green color. It dissolves in several of the mineral acids, especially the sulphuric. It has little taste, and scarcely reddens vegetal blues; it renders turmeric brown, like an alkali. The glacial acid, when exposed to the atmosphere, absorbs water, intumesces, and becomes opaque; it is readily fusible, and forms combinations with many of the metallic oxides having the same property. Its specific gravity before fusion is 1·48; afterwards 1·80. At a *white* heat this acid slowly sublimes when exposed to the air, and it sometimes happens that flashes of electric light are observed during the spontaneous cracking of a mass of fused boracic acid. When perfectly pure, and slowly deposited from its aqueous solution, it forms small prismatic crystals.

The green color communicated to the flame of alcohol is so peculiar, that it is resorted to as an indication of the presence of this acid. If a salt, free from copper, for example, be suspected to contain boracic acid, a little sulphuric acid may be added, and the mixture dried by a gentle heat; this will separate the boracic acid, and dispel any chlorine or hydrochloric acid that may be present, and which also gives a greenish-blue flame. Add alcohol to the dry mass, and ignite; if the smallest quantity of this acid be present, the green tint will sooner or later appear, especially if the mixture be stirred rapidly with a glass rod.

When boracic acid is perfectly dry, it is fixed; but during the ebullition of its aqueous solution, it is carried off by the vapor in large quantity. On being distilled with alcohol, a much larger portion of the acid is carried off in the spiritous vapor than by the steam.

This acid is so feeble in its affinities, that the law of division of acids and bases does not hold with it when in the liquid state. At a high temperature, however, the action is reversed; for if a mixture of sulphate of soda and boracic acid be heated to redness in a crucible, the sulphuric acid will be driven off in consequence of its volatility, whilst the fixed boracic acid will remain combined with the whole quantity of the base. In solution, however, sulphuric acid would deprive boracic acid of its base.

Boracic acid is composed of one atom of borium and three atoms of oxygen:—

		Centesimally represented.	
	Atomic weight.	Theory.	Berzelius.
1 Eq. of borium, ...	11	31·43	31·19
3 Eq. of oxygen, ...	24	68·57	68·81
1 Eq. of boracic acid, ...	35	100·00	100·00

and the crystallized hydrate consists of—

	Atomic weight.	Theory.	Davy.
1 Eq. of boracic acid, ...	35	56·45	57·00
3 Eq. of water, ...	27	43·55	43·00
1 Eq. of crystallized acid, ..	62	100·00	100 00

These crystals lose half their water at 212° Fahr.

Boracic acid is soluble in alcohol and oils. Potassium, at elevated temperatures, decomposes it with evolution of light and heat; sodium effects the decomposition quietly. Charcoal does not decompose it at a white heat. With salifiable bases, boracic acid forms a class of salts called *borates*, the principal of which, biborate of soda, will be subsequently described.

Payen gives an excellent treatise on the history and manufacture of boracic acid in Tuscany. He says:—The works established for the extraction of boracic acid greatly interest observers. They are situated on a gently sloping ground, constantly disintegrated by currents of gas and of vapors, which project liquid columns in the middle of small basins of water, and afterwards rise into the air in whitish clouds. At the bottom of these hills are situated the manufactories, not less than nine in number, at a short distance from each other. They are named Larderello, Monte-Cerboli, San Frederigo, Castel-Nuovo, Sasso, Monte-Rotundo, Lustignano, Serazzano, and Lago. In these establishments, in which an enormous mechanical force is incessantly manifested, and an evaporation exceeding seven thousand eight hundred and seventy-five tons effected, in which an annual production of about seven hundred and thirty-eight tons of crystallized acid is realised, neither machines, nor crude substances, nor combustibles, are perceptible. The *soffioni*—numerous jets of vapor—furnish everything; it is merely requisite to give their powerful blast a proper direction, to obtain both the crude solution and the heat required for its concentration.

Sir John Bowring, in writing on the lagoons, has the following apposite remarks:—The lagoons of Tuscany are unique in Europe, if not in the world; and their produce is become an article of equal importance to Great Britain as an import, and to Tuscany as an export. They are spread over a surface of thirty miles, and exhibit, from the distance, columns of vapor, more or less according to the season of the year and state of the weather, which rise in large volumes among the recesses of the mountains.

As one approaches the lagoons, the earth seems to pour out boiling water, as if from volcanoes of various sizes, in a variety of soil, but principally of chalk and sand. The heat in the immediate vicinity is intolerable, and one is drenched by the vapor, which impregnates the atmosphere with a strong and somewhat sulphurous smell. The whole scene is one of terrible violence and confusion—the noisy outbreak of the boiling stream—the rugged and agitated surface—the volumes of steam—the impregnated atmosphere—the rush of waters among bleak and solitary mountains.

The ground, which burns and shakes beneath the feet, is covered with beautiful crystallizations of sulphur, *et cetera.* The character beneath the surface of Monte Cerboli is that of a black marl, striated with carbonate of lime, giving it, at a short distance, the appearance of variegated marble. Formerly, the place was regarded by the rustics as the entrance of hell, a superstition derived, no doubt, from very ancient times; for the principal of the lagoons, and the neighboring volcano, still bear the name of Monte Cerboli—*Mons Cerberi.* The peasantry never passed by the spot without terror, counting their beads, and imploring the protection of the Virgin.

The lagoons have been brought into their present profitable action within a very few years. Scattered over an extensive district, they have become the property of Count Larderel, to whom they are a source of wealth; more valuable, perhaps, and certainly less capricious, than any mine of silver that Mexico or Peru possesses.

That these lagoons, so valuable to the proprietor and to other nations, in the commercial importance of their productions, should have been permitted to discharge their enormous yield of boracic acid unheeded into the atmosphere—that they should have been so frequently visited by scientific men, to none of whom, for ages at least, did the thought occur that they contained in them mines of wealth, is a curious phenomenon; nor is it less remarkable, that it was left for a man, whose name and occupation are wholly dissociated from science, to convert these fugitive vapors indirectly into gold, by processes which, though simple, are, nevertheless, eminently chemical.

Many difficulties have impeded this manufacture; but Count **LARDEREL** has succeeded in overcoming the most serious, by substituting, instead of the expensive wood fuel, a most happy application of the superabundant vapor which everywhere escapes from the soil, and by which a saving of nearly half a million sterling has been effected. Before describing the actual process of manufacture, and proposing a probable theory and possible improvements, **PAYEN** gives the results of his researches as to the nature of the gases, and of the substances which they carry with them into the lagoons —small muddy lakes.

The non-condensed gases were found to consist of—

	Centesimally.
Carbonic acid,....................	57·30
Nitrogen,........................	34·81
Oxygen,..........................	6·57
Sulphide of hydrogen,..	1·32
	100·00

The condensable products, and the substances conveyed by the currents of vapor, vary: generally they comprise water, clay, sulphates of lime, of ammonia, of alumina, and of iron, hydrochloric acid, organic substances with a *marine* smell, and lastly, little or no boracic acid; they deposit sulphur in all the narrow fissures and pores which they traverse. The temperature of these vapors was found to vary from 206° to 212° Fahr. With these observations, in connection with what follows, a probable theory of the production of boracic acid may be offered.

It has been found impossible to obtain this acid by condensing the vapors of the soffioni, even in very large and long tubes; to obtain it, it is requisite that their apertures should be directly covered by the liquid of the basins. It is frequently observed, that a portion of the water absorbed, when these lagoons are filled, is subsequently thrown up by the vapor. Thus the cause of the currents of gas, and of the elevation of the temperature, appears to have remained constant for many years; whilst the production, or at least the arrival of the boracic acid at the surface of the soil, seems to depend on the introduction of water into the fissures.

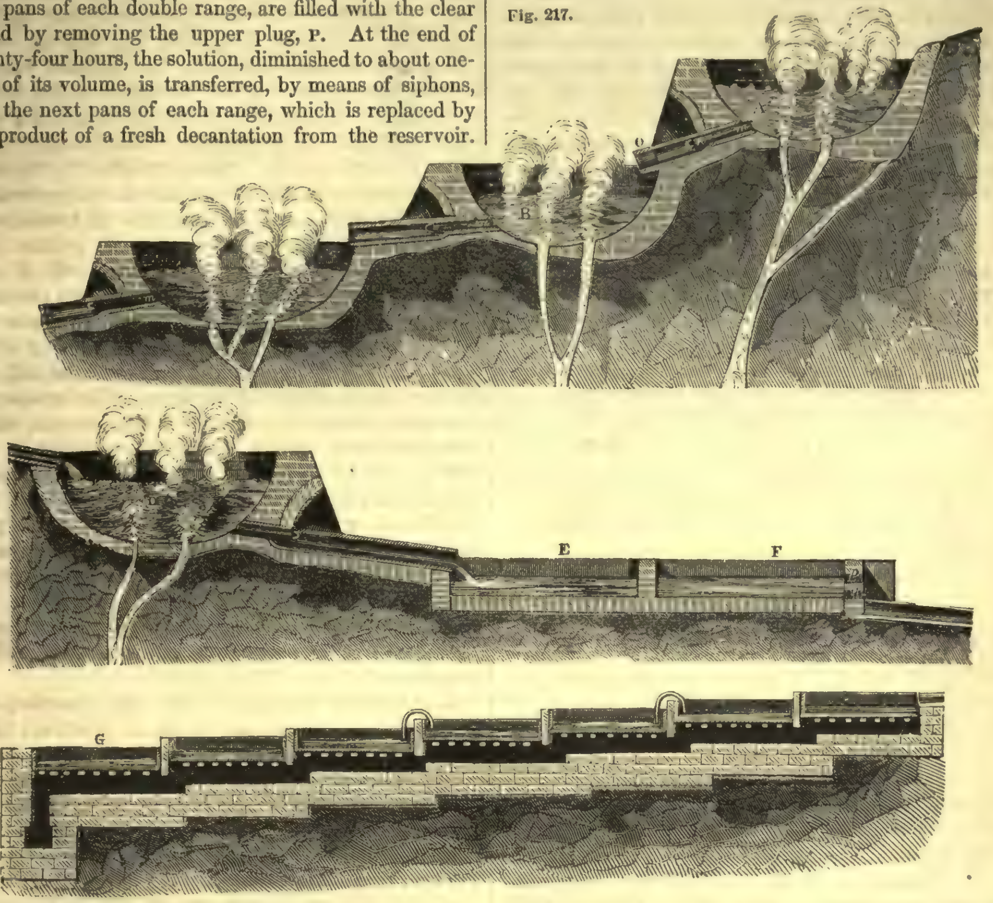
Suppose the water of the sea, percolating through some fissure to a great depth, had its temperature raised to a high degree, and that it found in the soffioni an issue for its vapors, all these phenomena would be intelligible; for the vapor, mixed with the projected water in passing over the deposits of boracic acid, would carry this with it, and by the reaction of the organic matter contained in it on the sulphates, would produce sulphides, from which boracic acid would expel sulphide of hydrogen.

These facts admit, however, of a more chemical explanation.

Let it be supposed, with **DUMAS**, that a deposit of sulphide of borium, situated at a great depth, came in contact with sea-water; a considerable action would take place, from which would result boracic acid, sulphide of hydrogen, a high temperature, carrying off these products with the water,—hydrochloric acid, arising from the decomposition of earthy chlorides, and ammonia, produced by the organic matters. If the action took place not far from the calcareous mass, the boracic acid, conveyed in the current of vapor, would decompose the carbonate of lime, and the equivalent of carbonic acid would mix with the other gases. At a certain distance, the sublimed boracic acid might form deposits, and, according as the waters of the lagoons descended to this point or not, the current would again carry up with it boracic acid, or pass without volatilizing it. The air furnished by the sea-water would enter the fissures, and in the presence of sulphide of hydrogen would determine the formation of sulphuric acid. This, in its turn, would produce sulphates of lime, of ammonia, of alumina, and of iron, taking the lime from the calcareous mass, the ammonia from the vapors, and the alumina and iron from the clay. These different salts, which are formed or which dissolve in the waters near the surface of the soil, explain the disintegration of the latter. The appearance of sulphur, and the presence of a little oxygen, which accompany the various substances contained in the soffioni, and in the troubled waters of the lagoons, would result from the accidental introduction of air. Another cause may have a great influence in the production of boracic acid; for instance, the reaction of sulphuric acid, so abundant in the masses of disintegrated soil, on the interiorly-formed borate of lime. It is possible that one day some of these deposits of borate of lime may be discovered by means of excavations and analysis.

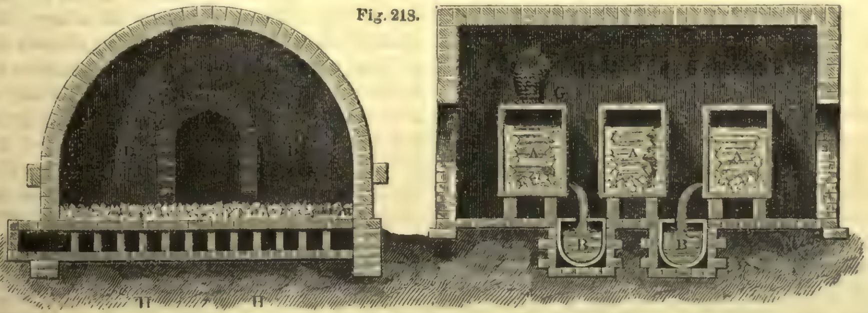
The methods adopted in the nine manufactories are, with some slight modifications, identical: they consist in the construction of rude circular basins —Fig. 217—around each of the centres of eruption, where two or several of the more considerable fissures terminate; and further, in conveying into the highest of these basins or lagoons, A, the water of some neighboring springs. After remaining there for twenty-four hours, during which these waters have been constantly agitated by the subterraneous vapors, the plug, O, is opened, and the liquid passes by a small canal, *m*, *n*, into the lower lagoon, B, where it is confined for the same time, and becomes charged with more boracic acid, and the accompanying substances. The solution is successively passed into the lagoons, C, D, and the liquid, drawn off from an inferior basin, is constantly replaced by that contained in the one above. All experiments made with a view of obtaining directly the boracic acid, by condensing the vapors in conduits, have been fruitless; only an acidulated water containing no boracic acid was obtained. When a solution has arrived at the last lagoon, D, and is sufficiently saturated, it is transferred into a reservoir, or cistern, E, twenty feet square, and a little more than two feet deep, where the greater portion of the sediment is deposited. The supernatant liquid is decanted either into a second reservoir, F, or two batteries, each of seven leaden evaporating pans, G G, ten feet in breadth, and fourteen inches in depth, supported by strong wooden rafters above the masonry, on an inclined plane, which allows the vapor of some soffioni, enclosed in drains, and which enters at H, to ascend freely beneath the pans, which are arranged on different levels, to the upper portion, where the excess is given off outside the factory. The solution of the boracic acid in the reservoirs usually has a very low specific gravity. The four first pans of each double range, are filled with the clear liquid by removing the upper plug, P. At the end of twenty-four hours, the solution, diminished to about one-half of its volume, is transferred, by means of siphons, into the next pans of each range, which is replaced by the product of a fresh decantation from the reservoir. Twenty-four hours later, the menstruum, again reduced to half its volume, is removed, by means of siphons, into the last two pans, while the superior two are again charged as before. The evaporation in the last two pans is continued for twenty-four hours, and the mother waters of a preceding crystallization mixed with it; the mixture then has a specific gravity of 1·07 to 1·08, at a temperature of from 173° to 176° Fahr. The whole of this solution is then brought into the crystallizing tubs, A A A—Fig. 218—which are constructed of wood and lined with lead. Here the crystallization is effected, and the produce of seventy-two hours' evaporation, derived each day from a battery of fourteen pans, affords one hundredweight and three quarters of saleable boracic acid.

Fig. 217.



This product diminishes in rainy weather. During evaporation, abundant deposits of sulphate of lime are formed, which have to be removed. When crystallization ceases, the mother lie is drawn off into tanks, and added to the liquid contained in the last evaporating pans; the acid is placed in baskets, G, to drain. It is then carried into the drying-room, D D, spread in layers on the floor, and turned from time to time. When it no longer moistens the hand on being pressed, it is formed into heaps, packed in casks, and forwarded

Fig. 218.



to Leghorn. The drying-room is constructed of bricks, and has a double floor, between which the vapor of some soffioni circulates.

The different manufactories contain from one to five batteries of from fourteen to sixteen pans, and each from three to twenty-five lagoons. In the manufactory of Larderello, which is the most considerable, there are eighty evaporating pans.

The largest lagoons, which are of an irregular circular form, are from fifty-seven to sixty-five feet in diameter, and the smallest from thirteen to sixteen feet; their depth varies from five to eight feet. The liquid in them attains a temperature of from 200° to 203° Fahr.

Unfortunately, the impurity of the acid increases each year, which is probably due to the progressive alteration of the disintegrated strata by the currents of vapors, and the infiltrations of water. The first products contained from ninety to ninety-two per cent. of pure crystallized acid; at present they retain from eighteen to twenty-five per cent. of foreign matters. The following is Wittstein's analysis of the crude acid:—

Boracic acid crystallized,	76·494
Water,	6·557
Sulphuric acid,	1·322
Silicic acid,	1·200
Sulphate of ammonia,	8·508
Sulphate of manganese,	traces.
Sulphate of magnesia,	2·632
Sulphate of lime,	1·018
Sulphate of soda,	0·917
Sulphate of potassa,	0·369
Sesquisulphate of iron,	0·365
Sesquisulphate of alumina,	0·320
Chloride of ammonium,	0·298
Organic substance,	traces.
	100·000

These impurities render it unfit for several applications, and occasion a useless expense in transport. They might be got rid of by subjecting the drained acid to strong pressure, purifying the product by washing, and treating the mother lies apart, which would afford alum that might be turned to account, and residues of sulphate of lime, clay, *et cetera*. Has the maximum of production been attained? This is not probable; to be convinced of the fact, and to find out the conditions favorable to a larger produce, it would be necessary to examine whether there exist accessible deposits of borate of lime, and to submit to numerous analyses the waters of the lagoons, after they have been in contact with the vapors a certain time. In this manner the proportions of acid, corresponding to the modified circumstances, would be found. Perhaps frequent additions of cold water into the soffioni, after having been left dry for some time, would be favorable to a more abundant extraction of the acid contained in the subterraneous deposits.

Count Larderel states, that at present there are four hundred evaporating pans in operation, each of ten feet surface; besides which there are several evaporating pans with diaphragms, arranged in rows, three hundred feet in length, in which the water, constantly vaporized, flows slowly through the different divisions, until at last it is so concentrated, that it may be conveyed at once into the cooling vessels. More than twelve hundred pounds of water are evaporated in the course of a day.

The production of boracic acid has increased in the annexed proportions:—

	Pounds, Tuscan weight.
1818–1828,	1,500,000
1829–1838,	14,000,000
1839,	2,152,000
1840,	2,527,752
1841,	2,547,804
1842,	2,655,139
1843,	2,655,202
1844,	2,655,200
1845,	2,655,000

The produce of the year 1846 amounted to about 3,000,000 pounds of boracic acid, and since then even this quantity has been exceeded.

Bowring remarks, that the powers and riches of these extraordinary districts remain yet to be fully developed. They exhibit an immense number of mighty steam-engines, furnished by nature at no cost, and applicable to the production of numerous objects. In the progress of time, this vast machinery of heat and fire will probably become the moving central point of extensive manufacturing establishments. The steam, which has been so ingeniously applied to the concentration and evaporation of the boracic acid, will probably hereafter, instead of wasting itself in the air, be employed to move huge engines, which will be directed to the infinite variety of production engaging the attention of laboring and intelligent artisans; and thus, in the course of time, there can be little doubt that these lagoons, which were fled from as objects of danger and violent dread by uninstructed man, will gather round them a large intelligent population, and secure sources of prosperity to innumerable individuals through countless generations.

The use of boracic acid is discontinued in medicine. It is now exclusively employed in the manufacture of borax.

BORAX.—Biborate of Soda;—*Soude boratée*, French; *Boraxsaures natron*, German; *Sodæ biboras*, Latin; *Plinias chrysocolla*, *Tincal*.—The word borax is derived from the Arabic *baurak*, a term applied by the Arabs to the *nitrum* of the Greeks and Romans.

Borax is a substance peculiar to the mineral kingdom. It has been found in some mineral waters, as those of San Restituta, or Ischia, and also in the waters of certain lakes, especially those of Thibet and Persia.

Common borax is soluble in about twelve parts of cold and two of boiling water. Heat resolves it into a porous, friable mass, known as *calcined borax*. At a red heat it runs into a transparent glass, which on exposure to the air becomes opaque and pulverulent on the surface. Its specific gravity in this state is 2·36. Anhydrous borax contains—

		Centesimally represented.	
	Atomic weight.	Theory.	Soubeiran.
1 Eq. soda,	31	30·690	31·416
2 Eq. boracic acid,	70	69·310	68·584
1 Eq. anhydrous borax,	101	100·000	100·000

and the common crystallized—

		Centesimally represented.	
	Atomic weight.	Theory	Gmelin.
1 Eq. soda,	31	16·23	17·80
1 Eq. boracic acid,	70	36·64	35·60
10 Eq. water,	90	47·13	46·60
1 Eq. common borax,	191	100·00	100·00

Sulphuric acid decomposes this salt, producing sulphate of soda and boracic acid. It is also decomposed by nitric and hydrochloric acids, and by the greater number of the vegetal acids. It is often used as a blowpipe flux, vitrifying a great many of the metallic oxides, and giving with them beads of different colors: blue with cobalt, amethyst with manganese, green with chromium and copper.

Its taste is saline, cooling, and somewhat alkaline. It reacts on turmeric paper like an alkali. On exposure to the air, it effloresces slowly and slightly.

NATIVE BORAX—TINCAL.—This substance occurs in prismatic whitish crystals, occasionally possessing a tinge of blue or green, and varying from translucent, or nearly transparent, to opaque. Taste, feebly alkaline; soft and brittle. Before the blowpipe it intumesces considerably, and then fuses into a transparent globule. It has been found in several localities; for instance, in India, China, Persia, Ceylon, and South America. It has even been met with in Saxony. Gathered on the banks of small lakes holding it in solution, it was formerly imported into Europe in great quantity, under the name *tincal*. It is always covered with an earthy incrustation, which is fatty to the touch, and smells of soap. This latter property is derived from a substance resembling soap, composed of soda and a fatty body, with which the crystals are coated to prevent the escape of the water of crystallization during the period it is being conveyed from one place to another. The fat can be separated by acids, and then assumes the appearance of a dark-brown rancid oil, soluble in ether.

From a very remote period, borax has been *refined* in the seaport towns, and more particularly in Venice—whence the appellation, Venetian borax, equivalent to the purified salt. At a later period, the process was introduced into the Dutch towns, and into France by the Brothers LECUYER. The operation has always been kept secret, nevertheless two different methods of purification have become known.

In one of these, the impurities are separated by lime, tincal being softened in a small quantity of cold water, and stirred about with a gradual addition of about one per cent. of slaked lime. The turbid lime-water is poured off, and when the impurities have settled down on standing, the clear liquid is again poured upon the crystals, and this process is repeated several times. In this manner, the greater part of the soapy compound is removed, and what still remains is separated by dissolving the crystals in hot water, and adding about two per cent. of chloride of calcium. Chloride of sodium is produced, and an insoluble lime soap, which is removed by straining, and the clear liquid is then evaporated to the consistence of 21° Beaumé, or specific gravity 1·17.

The other process consists in placing the powdered tincal in a tub, with holes pierced in the bottom, and washing it with a solution of caustic soda of 1·034 sp. gravity, as long as this passes through colored. The lie makes the soapy matter much more soluble. After draining, the crystals are dissolved in water, twelve per cent. of soda are added, which precipitates the foreign matters and earths; these must be strained off, and the lie evaporated to the consistence of 20° Beaumé.

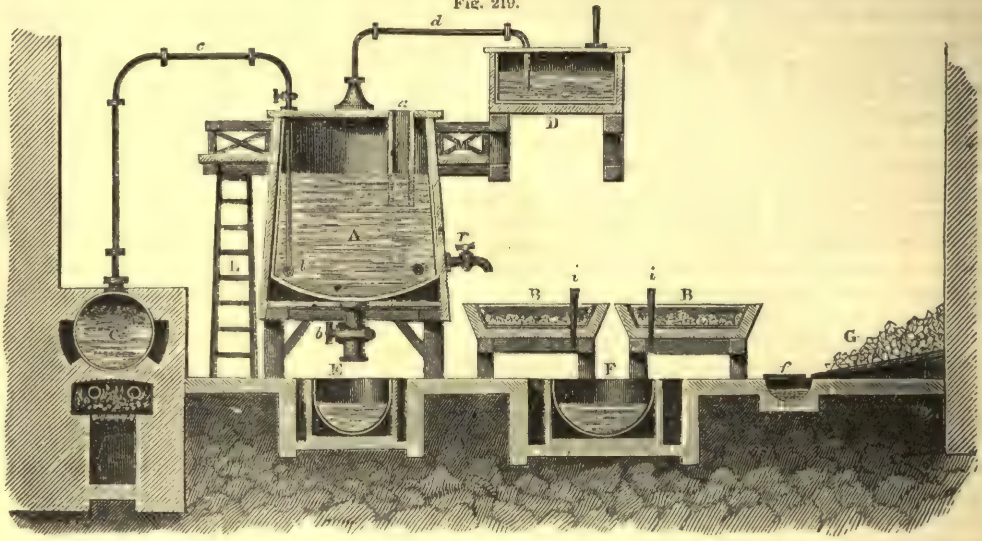
In both cases, the crystallization is effected in wooden vessels lined with lead, and having the form of short inverted cones. This shape is preferable, because the deposit which may form collects in the lower narrow part, and does not interfere with the crystallization. The use of lime facilitates the clarification, but may occasion a loss by the formation of insoluble borate of lime, for which reason the use of it cannot be very strongly recommended. Commercial borax, compared with that obtained from tincal, notwithstanding its greater purity, has one particular fault—that the crystals, when heated, split in the direction of their natural cleavage, fall to pieces, and fly off from the part required to be soldered; by which means a loss is occasioned, and the work retarded. The very great precautions used in the crystallization lessen this evil; but it is more effectually remedied by the addition of a small quantity of tincal before recrystallization.—*Knapp.*

So long as borax was obtained only from tincal, its price remained very high, and in 1815 it still brought in France from three to four shillings a pound. About this time began the fabrication of the salt from the boracic acid of Tuscany, and carbonate of soda. This process proving an economical one, is now exclusively used.

It consists in treating the boracic acid with crystallized carbonate of soda at a boiling temperature; the carbonate is decomposed, biborate of soda is formed, carbonic acid is disengaged, and the borax crystallizes as the liquid cools. At first view this preparation appears extremely simple; nevertheless, it encountered serious obstacles in the beginning, arising from the difficulty experienced in obtaining the crystals in a solid state and of a large size. PAYEN and CURTIER overcame this hindrance, and succeeded in preparing regular supplies of borax, in firm and large crystals, by performing the crystallization on a large scale, and conducting it as slowly and regularly as possible. This removed, another obstacle presented itself, which was not anticipated, and which is particularly pointed out, because it shows, in a striking manner, how prejudices often prevail, and lead the judgment astray. It happened, in fact, that commerce, accustomed to find in the Dutch borax a greyish tint, and crystals with the edges broken by the shaking of a long transport, did not approve of the new product. To obviate these prepossessions, it was necessary to imitate the Dutch article, and for that purpose to round the edges of the crystals by placing them in casks, which were made to turn on an axis. At the present day, these precautions are no longer required.

The manufacture will now be described. In a large wooden vessel, lined with lead and heated by steam, twenty-three hundredweight of crystallized carbonate of soda are dissolved in such a quantity of water, that the whole forms nearly two tons, when added to that produced by the condensation of the steam. The vats used for the dissolution of the soda are similar to A—Fig. 219. Steam enters the vat by a pipe, *c*, from the boiler, C; the tube reaches to the bottom of the vat, and terminates in a horizontal circular bend, *t*, which is pierced with holes for the elimination of the vapor. Two taps, *r* and *b*, serve to empty A; the opening, *a*, with its tube, is where the charge is introduced; this aperture is closed with a cover to prevent any loss of heat, or matters being eviscerated through it. Ladders, L, and balconies, M, are attached to the apparatus, for the convenience of the workmen to ascend and descend. When the solution of the soda is completed, the temperature is raised to 212° Fahr.; boracic acid is then added, in portions not more than eight to ten pounds at a time; the carbonate of soda is immediately decomposed, carbonic acid is disengaged with brisk effervescence, and biborate of soda remains in solution. If too much boracic acid were added at once, the evolution of carbonic acid would be so violent as to eject a portion of the lie. Among other gases eliminated with the carbonic acid, there is always a little carbonate of ammonia, which proceeds from the decomposition of the ammoniacal salts present in the crude acid. The apparatus is so constructed, that the gases and vapors shall pass through a tube, *d*, in the lid of the vat, to an adjacent condenser, D, containing sulphuric acid; sulphate of ammonia is thus produced, and the loss of a valuable secondary product prevented. To saturate the twenty-three hundredweight of carbonate of soda crystals, about a ton weight of Tuscan boracic acid, containing nearly ten per cent. of foreign matters, is employed.

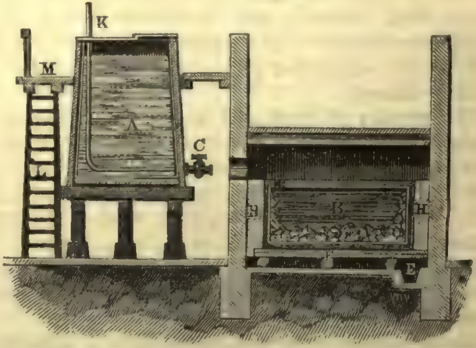
Fig. 219.



When the saturation is completed, the lie should have a specific gravity of 1·166 or 33° Twaddle; the steam is then arrested, the orifice, *a*, is closed, and the liquid is left to settle for ten or twelve hours, when the clear solution is withdrawn by the tap, *r*, into the shallow vessels, B B, lined with lead; the deposit falls through *b* into E, where it is washed, and then discarded. As the crystallization is completed in the vessels, B B, the leaden plugs, *i i*, are removed, and the mother lie drawn off to the common reservoir, F, to be used for the next saturating process. The crystals are detached from the vessels, B B, and are placed upon an inclined plane or board, G, to drain; the mother lie, adhering to the crystals, falls into the channel, *f*. Borax, formed in the first crystallization, must be submitted to a succeeding operation to purify it, and transform it into large crystals.

REFINING OF BORAX.—In a vat, A—Fig. 220—about nine tons of the crude borax, obtained as in the preceding, are dissolved at once, by means of water, heated by steam, and entering by the pipe, K; the solution of the salt is accelerated in a remarkable degree by placing the borax in a perforated cast-iron pan, or sieve, raised by a crane, and suspended under the surface of the liquid. The Editor is aware of the excellence of this arrangement, for the particles of fluid, as they become saturated and heavy, descend, leaving the less dense liquid in contact with the salt, till it becomes impregnated in like manner. When it is completely dissolved, some three or four hundredweight of carbonate of soda crystals are added to the liquor, and steam again allowed to enter, until the solution has a specific gravity of 1·166; after the attainment of which, it is drawn off by the tap, C, into the crystallizing vessel, B. The inclined floor, F, below B, is made of glazed stones, and any of the lie which may be thrown out of the crystallizing pan, B, by the force of the liquid descending from the vat, A, flows along it to the chan-

Fig. 220.



nel, E, where it collects. The crystallizers are large wooden vessels, lined with thick sheet-lead, and about five or six feet deep, four feet wide, and twenty to thirty feet long; they are situated in an external box, with which, however, they are not in contact, the intermediate space being occupied by coarse wool, sawdust, or small coal, in fact, with any matter which is a bad conductor of heat, and represented in the figure by H. The vessels are besides covered over tightly with a lid made of stout boards lined with lead, in order that the cooling of the liquor should be very gradual, as this is requisite to the production of large and well-defined crystals of the salt.

It is by taking all these precautions, and especially by using suitable crystallizers, that success has been achieved in obtaining the large crystals required for several applications. According to the external temperature, the crystallization should continue from twenty-five to thirty hours; it is finished when the liquor ceases to indicate a temperature of not more than 82° to 88° Fahr.; at this point the mother water must be abstracted by means of a siphon; a man then wipes briskly the edges of the crystals with a sponge; that done, the cover is replaced, and they are left for some hours to cool, in order that the crystals, *being suddenly set* by the cold, may not become friable.

The crystals, adhering strongly to the sides of the crystallizer, are detached, after drying, with a chisel and heavy strokes of a mallet; they are separated from one another with a small hatchet, the small crystals taken out, and then they are enclosed in cases, resembling the old Dutch packages.

The octahedral borax, discovered by PAYEN, presents this advantage, that when crystallized it contains less water by half than the ordinary salt. It crystallizes in a solution more concentrated than that which produces the prismatic borax, and within higher limits of temperature. The operation is, therefore, the same as that which has just been described, only the solution of crude borax should have a specific gravity of 1·256 to 1·30, or 50° to 60° by Twaddle, when withdrawn into the large crystallizers. The crystallization commences at a temperature of 174° Fahr., and the octahedral borax ceases to form at 133° Fahr.; at this point, therefore, the mother waters, which yield by further cooling nothing but prismatic borax, ought to be quickly removed.

The crystals of octahedral borax adhere strongly among themselves; they form plates of small thickness, very hard and sonorous. Contrary to prismatic borax, they effloresce in a very moist atmosphere, or even when immersed in water; they tend, in these circumstances, to absorb a quantity of water, equal to that which they already contain, and to pass to the composition of prismatic borax. In other respects, these two descriptions of borax have the same properties.

Several patents have been taken out for improvements in the manufacture of this salt.

M. KOEHNKE gives the following directions for carrying out his process:—In the preparation of borax from common crystallized carbonate of soda and crude Tuscan boracic acid, a solution of caustic soda is made, amounting to about one hundred and seventy pounds, of 1·090 to 1·095 specific gravity, which requires on the average fifty pounds of soda and thirty pounds of good caustic lime, the latter mixed to a paste with four times its weight of water. When the mixture has been boiled in an iron pan, and converted into caustic lie, it is carefully covered, and after the lapse of a few hours, the clear solution is siphoned off, the residue again treated with a further quantity of water, well agitated, and the clear liquid again drawn off after a few hours' rest. A further quantity of water is poured over the residue, which is subsequently removed, to be employed in washing the crystals of borax obtained.

The lies thus obtained are boiled down to 1·090—1·095 specific gravity, and then forty pounds of good Tuscan boracic acid introduced, and further boiled until the lie is reduced to the specific gravity 1·175—1·180. Upon this the liquid is poured boiling-hot into a wooden tub, which is well surrounded with woollen cloths and straw, and carefully covered to retain the heat as long as possible, so that a good and regular crystallization may be effected.

When borax crystallizes from a warm solution at from 95° to 105°, octahedral crystals are obtained, which contain only five atoms of water of crystallization, and, consequently, entail a very considerable loss in product. This is not to be feared in the above process, but great attention should be paid to the specific gravity of the lie; for if the hot lie, placed aside to crystallize, has been reduced by boiling to beyond 1·180, octahedral crystals are likewise obtained. It should, moreover, be observed that the boracic acid, which has been introduced according to the above directions for the first time, is by no means sufficient to convert the whole of the soda into biborate; but an excess of alkali has a very beneficial influence on the crystallization. It is, moreover, advantageous not to remove the dissolved lime from the caustic lie, but rather to add a little free caustic lime, as this serves partially to destroy the sulphates contained in the crude boracic acid. After three days the first crystallization is complete. The crystals are collected and broken, washed with the above-mentioned dilute alkaline liquid, and placed aside; the borax lie, on the contrary, is mixed with the wash liquors and placed aside, in order that it may deposit the sulphate of lime formed, and other impurities. As soon as the menstruum has become clear, it is carefully drawn off, boiled down, and during this operation eight pounds more boracic acid gradually added to it, and it is then treated as above The remaining liquid still requires from two to five pounds boracic acid. What remains after this third crystallization, may be saturated with sulphuric acid, and obtained as sulphate of soda.

The recrystallization of the product obtained must generally be repeated twice; for which purpose it is dissolved in two and a half parts of rain-water, the lie brought by boiling to the above specific gravity, and conveyed in a state of ebullition into a wooden vessel protected from rapid cooling. The evaporation of the residuous lie is repeated. The crystallization is always terminated within two or three days. There is no need of filtration except on the last recrystallization. The product amounts, when good substances have been employed, and with careful treatment, to from sixty to sixty-two pounds of pure borax.

The preparation of borax from crude soda and boracic acid is more advantageous, but at the same time more difficult; for this purpose, a solution of caustic soda is likewise made, amounting to three hundred pounds of 1·090—1·095 specific gravity, which requires about one hundred pounds of crude Alicant or Teneriffe soda, and from forty-five to fifty pounds caustic lime; the lie is prepared in the same manner, and from forty-five to forty-eight pounds of Tuscan boracic acid added to it, upon which the lie is concentrated to about one hundred and eighty to one hundred and eighty-five pounds, or specific gravity 1·175 to 1·180; in the meantime the froth is now and then removed, and finally the whole placed aside to crystallize. To the first mother lie from eight to ten pounds of boracic acid are added, and to the second two or three pounds more; frequently, however, according to the substances employed, even as much as ten pounds, which must be determined by a previous examination of the borax lie. The mode of operation is precisely the same as described in the preceding method. A greater quantity of sulphate of soda is, however, obtained on saturating the last mother lie with sulphuric acid. The produce in crystallized borax amounts to from eighty to ninety pounds. The third method relates to the preparation of the biborate of soda from the half-refined East Indian borax, which contains considerable quantities of smeary or fatty ingredients; it is washed with a soda lie of 1·370 to 1·380 specific gravity, and then, since it always contains a large excess of soda, it is gradually saturated with Tuscan boracic acid, as described in the previous methods, and purified by three or four recrystallizations. The produce may amount to sixty-five, and in a favorable case to seventy-five per cent. crystallized borax.

Sautter took out a patent, the object of which was to avoid the use of water in the manufacture of borax, and to give a product possessing the same properties as the crystallized borax manufactured by the usual process, but of an entirely different appearance, being in a granular state, and of a dull white color when quite pure. The advantage of this invention is to produce an article, endowed with the same chemical properties, and of precisely the same composition, at a considerably less cost than the borax now in use. It may be added, that its being in a granular state makes it more convenient for the making of glass enamel, *et cetera*. This new borax is made in the following way:—About thirty-eight parts by weight of boracic acid, quite pure, crystallized, and dry, are taken and sifted; then about forty-five parts in weight of fine carbonate of soda, reduced to a powder, added. These two powders are to be thoroughly mixed together by any convenient means. The mixture is then to be placed in a room, the temperature of which is heated to about 90° to 115° Fahr.; it is placed in layers or beds, of about one inch thick, upon wooden planks. The action of the heat upon the mixture causes the boracic acid to combine with the soda, and the carbonic acid is driven off from the carbonate of soda, together with the superabundant water contained in it, forming, without the aid of water, a perfect borax, possessing all the chemical properties of the salt now obtained by means of crystallization. The layers should be left during from twenty-four to thirty-six hours, being occasionally stirred; after which the operation is completed, and the new borax is found in the state described, ready for the market. This description applies more particularly where both substances are used in their purest state; impure acid can, however, be also employed, and the reaction will take place just in the same way, and offer proportionally the same advantages over the actual mode of manufacturing borax by crystallization; but an impure product will then be obtained, which, however, not being objectionable for certain purposes, might also be used.

Fused borax, as stated at page 347, has the property, at a high temperature, of dissolving the metallic oxides, and transforming them into transparent and colored glasses.

This remarkable property, turned to advantage in blowpipe experiments, is likewise the basis of the chief application of borax in manufacturing operations. It is well known, indeed, that this product is indispensable in some kinds of soldering, and that it is applied to preserve from oxidation the parts intended to be joined together.

For several years borax has been introduced into the composition of fine glasses and pastes; it has also been long employed in the preparation of coatings for English porcelain.

In these latter applications, the borax, provided it be pure, does not require to be crystallized; it would even be preferable in the anhydrous state, as produced by Koehnke.

Analysis.—The assay of borax may be made very easily by a process contrived by Gay-Lussac, and similar to that employed in alkalimetry. Since sulphuric acid decomposes borate of soda in a complete manner, if sulphuric acid of a known strength be employed, the quantity which will have been required to decompose a known weight of borax, will indicate the quantity of soda contained in the salt; and, therefore, the proportion of borax, which corresponds to that quantity of soda, may be readily calculated.

The *modus operandi* is as follows:—Dissolve one hundred grains of the borax under examination in about one thousand grains-measure of pure water, with the help of heat, and add thereto a few drops of tincture of litmus, so as to impart a blue tinge to the solution. This done, pour into an alkalimeter one thousand grains-measure of test-sulphuric acid, of specific gravity 1·032—one thousand grains-measure contain one equivalent of dry acid, and can, therefore, neutralize one equivalent of each base—and add it gradually to the solution of the borax. The liquid at first assumes a fine purplish hue, and at last one or two drops of the test-sulphuric acid in excess changes it into the characteristic color, which indicates that the point of saturation is obtained. In order, however, to detect this change of color more easily, Gay-Lussac recommends to tinge a similar quantity of water reddened by litmus, with two drops ot test-sulphuric acid, and to compare the tint of this liquor with that of the solution of borax under examination. As the boracic acid contained in the hot solution of borax, and which is deposited when the point of saturation is attained, interferes with the ready appreciation of the changes of color, the solution should be allowed to cool before adding the last drops of acid. When the tinge produced in the borax liquor is exactly like that of the colored water kept for comparison, the operator reads off the number of divisions of the test acid employed, and then calculates therefrom the value of the borax assayed. The indication is a little too high, because it is necessary to pour a slight excess of acid to produce a distinct reddening, and it is, therefore, customary to deduct three drops from the number indicated by the alkalimeter.

The number of divisions, as before stated, represents the quantity of real soda contained in the borax: let it be supposed, then, that fifty divisions have been required to decompose one hundred grains of borax analysed; since one hundred divisions represent one equivalent, or thirty-one of soda, it is evident that, in that case, only one-half equivalent, or 15·50, of soda were present in the one hundred grains of borax.

Now pure borax consists of—

1 Eq. of soda,	31
2 Eq. of boracic acid,	70
10 Eq. of water,	90
1 Eq. of borax,	= 191

The operator may, therefore, easily calculate what quantity of borax corresponds to the 15·5 grains of soda found in the experiment:—

	Soda.		Borax.		Soda.		Borax.
If	31	:	191	::	15·5	:	95·5

Consequently, in the case above alluded to, the sample contains 95·5 per cent. of crystallized borax.

The adulterations generally consist of *common salt* and *alum*. These impurities may be easily detected; the first, by solution of nitrate of silver, which will immediately produce a white curdy precipitate of chloride of silver, insoluble in nitric acid, soluble in a slight excess of ammonia, and which may be separated by filtering, or by decantation after it has well settled. The presence of alum is recognized by the white bulky precipitate which ammonia produces when poured in the liquor, which precipitate is soluble in a solution of caustic potassa. The adulteration of borax with alum is sometimes so considerable, that, on adding ammonia, the whole solution stiffens into a thick jelly. When this is the case, the presence of alum may be readily detected, even by the taste, the alum having a styptic, astringent, *slightly acid* flavor, whilst that of borax is sweetish and *slightly alkaline;* and the solution, if it contains alum, reddens the tincture of litmus, whilst that of borax, on the contrary, renders reddened litmus paper blue again. If the borax has been falsified with one-tenth part of its weight of alum, it does not completely dissolve in water; that is to say, the liquor remains turbid, and a slight whitish sediment settles down in the glass.

ROSE, in a paper upon boracic acid and its quantitative estimation, states the following facts:—It is well known that various difficulties are met with in the estimation of boracic acid, which as yet have not been entirely overcome by the methods recommended. When boracic acid is dissolved in water, its entire amount cannot be obtained by evaporation; moreover, when the acid, procured in this way from its aqueous solution, is heated to fusion in a platinum crucible, its weight continually decreases, unless access of air be most carefully prevented. The decrease in weight becomes far more considerable when the temperature is raised to a strong red heat. This loss, however, amounts only to a few milligrammes, unless the heating occurs in a moist atmosphere; but if the cooled boracic acid is moistened with a drop of water, and again heated to redness, the loss in weight amounts to some centigrammes, and it is far beyond this when a drop of alcohol is used instead of water. The deficiency of weight which occurs in melting boracic acid, is best avoided by placing a small quantity of carbonate of ammonia upon the surface of the acid.

It has been proposed to prevent the volatilization of the boracic acid, on evaporating its aqueous solution, by supersaturating it previously with ammonia; but the affinity of boracic acid for ammonia is so slight, that the latter is expelled with the aqueous vapor.

Even the addition of chloride of ammonium to a watery solution of boracic acid, does not hinder the volatilization; for on evaporating the whole, after the addition of this salt, and heating the dry residue in a platinum crucible until no more fumes of chloride of ammonium are liberated, a residue is obtained which cannot be fused at the temperature at which pure boracic acid readily melts.

On treating the mass with water, nitride of borium is left undissolved, in the form of a whitish-grey powder; its quantity varies, and sometimes not even a trace is produced.

It is likewise impossible to determine the boracic acid quantitatively, in its aqueous solution, in a similar manner to arsenic and phosphoric acid, by adding to the solution a weighed quantity of recently-calcined oxide of lead, evaporating the whole, and heating or igniting the dry mass; for the escape of boracic acid on evaporation cannot be prevented by the addition of oxide of lead. Nitrate of lead is as useless for the purpose as pure oxide. No quantitative result can be obtained, even by the addition of a weighed quantity of tribasic phosphate of soda, for this salt does not prevent the volatilization of the boracic acid from its watery menstruum. In fact, it is only possible to estimate, quantitatively, the boracic acid in its aqueous solution, by the addition of a weighed quantity of a fixed alkaline carbonate. This method is somewhat tedious, and requires much time and attention. Carbonate of soda is preferable to that of potassa, as it can be more readily weighed off with accuracy. The alkaline carbonate is weighed in the fused state, and about the same or twice the amount of the boracic acid, supposed to be present in the solution, is taken for the experiment. It is dissolved in the solution, and the whole evaporated at a gentle heat. At the ordinary temperature, carbonic acid is not expelled from the carbonated alkalies by the free boracic acid; and at a higher temperature, as also on evaporation, only in a very slight degree: it is only after the whole has been evaporated to dryness, and the dry mass is strongly heated, that any evolution of carbonic acid takes place, at which time it is necessary to be particularly careful. With a strong heat the mixture is liquid, but at a lower temperature, only tenacious. If it be fused over a spirit-lamp having a double draft, a constant weight is obtained on cooling, which does not vary even after long standing; but if the crucible be exposed to a moderate heat, after having been previously exposed to a strong red one, it curiously enough increases in weight, and it is not possible to obtain by this means a constant result. Moreover, the weight is the same, whether the fusion of the mass has been continued for a longer or shorter time, and whether a higher or lower temperature has been employed.

The carbonic acid in the fused mass is now estimated. If from the weight of the fused mass, the amount of soda in the carbonate of soda originally employed be subtracted, and that of the carbonic acid which has escaped during the experiment, the quantity of boracic acid is obtained with great accuracy.

The same phenomena occur with the employment of carbonate of potassa, but as this salt is more deliquescent, it cannot be weighed with the same degree of accuracy as the carbonate of soda, consequently the results are not accurate. This method of estimating the amount of boracic acid in its aqueous solution, can, however, be rarely employed, and only when the solution contains no other substance than perhaps ammonia, which is expelled, even without the action of carbonate of soda. The best and most accurate method of separating boracic acid from bases is, as is well known, by means of hydrofluoric and sulphuric acids, when the boracic acid is expelled as fluoride of borium, and the bases are obtained in the state of sulphates. But boracic acid may likewise be entirely expelled as boracic ether, by treating the borates with sulphuric acid and alcohol. This process, however, is far less accurate than that by means of hydrofluoric acid, and should only be employed when concentrated hydrofluoric acid cannot be procured. When hydrochloric acid is used instead of sulphuric acid, as proposed a long time since, the boracic ether is far less easily produced, and its volatilization very slow and incomplete. Since boracic acid does not form with any base a compound which is entirely insoluble in water, no direct method of estimating this acid is as yet known. The only compound, by means of which it might be completely separated, is the fluoboride of potassium; this salt is very sparingly soluble, and resembles the silicofluoride of potassium, and like it is insoluble in alcohol. It is more soluble in a solution of chloride of ammonium than in pure water. A great number of experiments has shown that it is not possible to separate boracic acid, quantitatively, as fluoboride from its solution. When pure hydrofluoric acid is added to the liquid, and then carbonate of lime, to separate the excess of acid, and, lastly, acetate of potassa and alcohol to the filtrate, a fluoboride of potassium is obtained, which always contains fluoboride of calcium; if, however, the boracic acid be combined with a base, for instance with soda, and the above plan be adopted, the results are far less accurate. With regard to the separation of boracic acid from phosphoric acid, Von Kobel has proposed to effect it by adding to both solutions one of sesquichloride of iron, and then precipitating the whole by an excess of carbonate of lime. The addition of the sesquichloride is, however, unnecessary. When hydrochloric acid is added to the solution of a borate, and the whole is treated in the cold with an excess of carbonate of baryta, no boracic acid is contained in the insoluble residue, which consists solely of carbonate of baryta. Phosphoric acid, on the contrary, both in the free and combined state, is entirely precipitated in the cold by carbonate of baryta, when some nitric or hydrochloric acid is added to the solution. Boracic acid can, therefore, be separated from phosphoric by carbonate of baryta. The greatest accuracy, however, is not attained by it, as the phosphate of baryta is not perfectly insoluble in a solution of borax. When phosphate of baryta is digested in the cold with a concentrated solution of borax, and filtered, the filtrate contains, after a time, traces both of baryta and phosphoric acid, which latter is readily detected by molybdate of ammonia. When, therefore, a mixture of phosphate and borate, after the addition of hydrochloric acid, is treated in the cold with an excess of carbonate of baryta, frequently stirred and filtered, after twenty-four hours the filtrates, even when long edulcorated, leave a residue on evaporation, and show, with molybdate of ammonia, traces of phosphoric acid. Still, if the insoluble residue, after having been washed for a time, is dissolved in hydrochloric acid, the baryta removed by dilute sulphuric acid, the phosphoric acid precipitated as ammonio-phosphate of magnesia, and the amount of phosphoric acid calculated from the calcined residue, a loss of the latter is found, but it is not considerable; so that a result, approaching very closely to the truth, may be obtained according to this method. When ammonio-phosphate of magnesia is digested in the cold with a concentrated solution of borax, no phosphoric acid can be detected in the filtrate; hence, when a solution contains boracic and phosphoric acids, the latter may consequently be separated by precipitating it as ammonio-phosphate of magnesia, unless the solution contains, at the same time, other substances, which are precipitated on the addition of ammonia and a solution of magnesia. The precipitate contains a very slight trace of boracic acid; and on this account a small excess of phosphoric acid is obtained, which is about as great as the loss which occurs with the method by carbonate of baryta. If the solution be acidified with nitric acid, an excess of carbonate of lime added, and the whole heated and filtered, the insoluble portion does not contain the whole amount of the fluoride of calcium, corresponding to the fluorine in the solution. Fluoborides have been formed, which are not at all or only partially decomposed by treatment with carbonate of lime. Boracic acid can be entirely separated from bases in insoluble compounds, by fusion with an excess of carbonated alkali. At least, on fusing borate of baryta and borate of magnesia with carbonate of soda, and treating the fused mass with water, the total amount of the bases was obtained, perfectly free from boracic acid.

The manufacture of borax in England is confined to one firm in the neighborhood of Liverpool, and the weight annually produced is near two thousand tons. The average price of this article is forty-eight pounds per ton, boracic acid costing about ten pounds per ton less.

Imports of Boracic Acid and Borax.

Years ending 5th Jan.	Boracic acid.	Borax.	Total.
	tons.	tons.	tons.
1843	749	42	791
1844	753	71	824
1845	679	138	817
1847	665	168	833
1848	1110	33	1143
1849	1210	338	1548
1850	720	195	915
1851	850	433	1283

The duties on borax imported into the United Kingdom were repealed in 1845. In 1852 the imports and exports of refined borax were respectively eighty-eight and eleven tons; and those of crude borax or tincal, two hundred and eighty-six and sixteen tons.—*M'Culloch.*

BREAD.—*Pain*, French; *brod*, German; *panis*, Latin.—Modern researches in the organic department of chemistry, and the rapid progress that has been made, in consequence of the more perfect methods of analysis, have invested with a new interest the subjects that will be discussed under this head.

Nations from the earliest periods, as they approached civilization, became, as it were, instinctively aware of the necessity of providing a more certain means of satisfying the cravings of appetite, than the chase could afford; hence the introduction of agriculture has been one of the most effectual of human means to bring about that conversion from the barbarism inherent in man, when left only to batten on a moor. This art is one of the conditions imposed upon man in consequence of his fall; and it continues to be the mainstay of human existence. It is observed that of all the material interests influencing humanity, there is none which so completely and so tyrannically fetters the individual as the care for his daily bread; and though this great feature is evinced by different pursuits in life, yet these, like so many tributary streams and rivulets, are continually meandering till they terminate in the all-absorbing ocean of agriculture, which is the soul of all the other branches of industry invented in modern ages; without it, none other can stand. It is that art on which a thousand millions of men are dependent for their very life; in the prosecution of which about nine-tenths of the fixed capital of civilized nations are embarked; and upon which more than two hundred millions of human beings expend their diurnal labor; the parent and forerunner of all the other arts.

Is it not strange that those engaged in the cultivation of the land are, as a body, amongst the most unscientific in the industrial pursuits of ancient and modern times? A paramount obstacle to scientific agriculture in the farmer, is the great difficulty which the solution of natural science always presents to the investigator; and as nature's operations lie at the foundation of agriculture, the philosopher can, in numerous instances, go no further in offering an explanation than the humble husbandman.

Nothing repays the toil of the laborer more fully than the willing soil; nothing is more grateful for his services, or offers surer rewards to patient industry, or to renewed attempts at improvement. The awakening spirit of the age is making itself felt in the remotest agricultural districts; old prejudices are dying away, and the cultivators of this most ancient, most important, and noblest of pursuits, are becoming eager for improvement. The Editor can justly say, that science is never unwilling to lend her hand to the practical arts; on the contrary, she is ever ready to proffer her aid, and it is not until her services are rejected that she refrains from taking part in their onward progress.

Agriculture in former days, remarks Johnston, crept timidly along the river sides, or sunned herself in sequestered glades or nooks, and reaped her crops under the protection of the sword; now, she boldly climbs the steepest mountains, and on their tops exhibits the trophies of her industry—her sheaves of golden corn.

The preference instinctively given to the cereals above other productions of the soil, as being most perfectly adapted for man's food, is, according to modern science, wisely implanted; their constitution bears a remarkable analogy to milk, and their effects in sustaining life are precisely similar.

Grain, or the material part which is rendered useful as a nutritive substance, is composed, like milk, of nitrogenous and non-nitrogenous substances, and inorganic salts; the former of which chiefly produce the blood, and are, therefore, the most nutritive; while the organic portion of the latter is almost exclusively destined to maintain the heat of the body, and is, consequently, called respiratory food.

From the preceding it may be understood how greater value is attributed to certain kinds of alimentary substances than to others—the former contain more of the nitrogenous, or blood-producing principle. Another cause of the value of such substances may be recognized in the fact, that the product of agriculture, in all civilized countries, is considerably greater in heat-producing bodies than in the blood-producing; and the latter, being rightly esteemed of greater importance in supporting life, have always commanded a higher value.

Indeed, the amount of nitrogen which any genuine article of food contains, is the criterion of its quality and price in the market; for as physiologists and chemists have ascertained that nitrogen is a component part of those substances of the food which immediately contribute to the production of flesh and blood, it follows that, when the amount of this element is known, the accumulated quantity of those constituents will thereby be ascertained, so that the value of any particular kind of food may be determined. A nutritive material, however, must not be wholly compounded of the nitrogenous, but of a mixture of these and the non-nitrogenous bodies, as the latter are as necessary to the development of the frame as the former.

The cereals, as has been wisely ordained, contain the proper proportion of both of these essential portions, some of which are richer than others, and, consequently, are the more highly prized. Professor Horsford, in investigating the relative values of different substances as articles of food, tabulated the annexed results for various kinds of wheat, which show the quantity of nitrogen in each when in the fresh state; *id est*, their relative nutritive power:—

Horsford.	Per centage of nitrogen.	Equivalents or weights for an equal amount of nutritive power.	Per centage of water.	Practical equivalents.
Talavera wheat from Hohenheim,	2·59	100	15·43	100
Whittington,	2·68		13·93	
Sandomierz,	2·69		15·48	
Wheaten flour from Vienna, No. 1,	3·00	90	13·85	—
" " " 2,	2·12		13·65	
" " " 3,	3·44		12·73	
Common winter wheat,	2·79	104	13·80	102
One-grained wheat—Triticum monococcum—from Giessen,	2·07	128	14·40	124

The fourth column in the above table indicates the practical equivalents of the nutritive powers of these substances, as ascertained by BOUSSINGAULT's experiments on the feeding of cattle.

Wheat is most fruitful in nitrogenous matters, in fact it is much more so than any of the other cereals. As cultivated in this country, it is of several kinds, which take their rise from that known as *Triticum Vulgare;* there are two other sorts, the *Triticum Æstivum*, or summer wheat; and the *Triticum Hibernum*, or winter wheat; and these again, from intermixture and various other causes, are broken up into separate species. *Triticum æstivum* is generally tilled in spring, and the proper season for sowing the winter wheat is in autumn.

Wheat is composed of an exterior integument or shell, covering the nourishing matters; the former constitutes from fourteen to sixteen per cent. of its weight when it is good, but the proportion is greater as the grain is poorer. It generally happens that no more than the one-tenth, and frequently only about one-eighth or one-ninth, is removed by grinding.

The floury part of the grain is composed of vegetal gelatin, fibrin, gluten, oil, albumen, starch, sugar, gum, water, and inorganic salts. These constituents are divided into the nitrogenous, which embrace the vegetal gelatin, fibrin, albumen, and oil; and the non-nitrogenous, which include the starch, sugar, gum, and inorganic salts. To understand the part which these severally perform in rendering the grain nutritive to the body, it will be desirable to say a few words upon each. Flour, when kneaded with a little water—or better, when a small stream of water has been directed upon it, supported by a thin cloth—becomes entirely disintegrated, in consequence of the soluble portions being carried away in the water, while the small starch granules are mechanically taken up, and there remains a tough substance unaffected by water. At first, the water, as it percolates through the cloth, has a milky appearance, and the matter upon the filter or cloth becomes shorter and more porous up to a certain period; as the filtrate passes off clearer, the mass remaining agglutinates into a compact body, which is known as *crude gluten*, but really consisting of vegetal gelatin and fibrin. Crude gluten does not swell when treated with water, but combines with a definite quantity, acquiring a certain degree of tenacity, which, however, is not increased by any further addition of water; it is not liable to decomposition for some time, and is very adhesive to solid bodies, such as the sides of vessels, paper, linen, *et cetera*, whenever it comes in contact with them; it may, however, be detached by immersion in water, or, in the case of linen or cloth, by moistening the contrary side. Boiling alcohol readily separates the crude gluten into a soluble and an insoluble substance; the insoluble is pure vegetal fibrin, and the soluble contains vegetal gelatin, to which the adhesive property of the crude gluten is attributed: by treating the latter with ammonia, the gelatin is dissolved and the fibrin remains.

According to JOHNSTON, the alcoholic solution of the crude gluten deposits, on cooling, a substance similar to casein, and on concentrating the residuary liquid a mucilaginous mass is obtained, consisting of oil and the adhesive substance, which he calls gluten. Both of these may be separated by ether, which dissolves the oil, the properties of which are found to be analogous to those of the other fatty oils. A considerable portion of this oil is carried away in the first maceration with water, and is found deposited with the starch; it may be removed by treating the starch with ether, filtering, and evaporating the solution, when it remains as a residue. Wheat generally contains from one and a half to three per cent. of the oil. KNAPP states that the manner of culture sensibly affects this quantity. The following are the results obtained from various specimens of wheat, cultivated as below stated:—

	Oil per cent.
1. Sample from undressed soil yielded of fatty matter,	1·4
2. Sample from soil dressed with guano and wood ashes,	1·9
3. Sample from soil dressed with artificial guano and wood ashes,	2·2
4. Sample from soil dressed with sulphated urine and wood ashes,	2·2
5. Sample from soil dressed with sulphated urine and sulphate of soda,	2·0
6. Sample from soil dressed with sulphated urine and common salt,	2·7
7. Sample from soil dressed with sulphated urine and nitrate of soda,	2·3

Thus it frequently happens that the same plant, taken from different parts of the field where it grew, is different in its composition, and not only this, but even parts of the same plant are found to vary. Such extraordinary peculiarities cannot otherwise be accounted for, than by assuming that the several members of the plant have various functions to perform, which require a suitable, and perhaps different, structure and arrangement of components; nevertheless, the approximate amount of the inorganic part of the plant must remain the same, whether or not certain bodies replace one another.

JOHNSTON's table of the relative quantity of ash or mineral constituents, yielded by different samples of ground wheat from the localities named, is annexed:—

	Ash in a hundred parts of dry			
	Fine flour.	Boxings.	Sharps.	Bran.
Sunderland Bridge, near Durham,	1·24	4·0	5·8	6·9
Kimblesworth,	1·15	3·8	4·9	6·7
Houghall,	0·96	3·0	5·6	7·1
Plawsworth,	0·93	2·7	5·5	7·6
Stettin,	1·01	4·5	6·2	6·9
Odessa,	1·01	4·9	6·6	8·0

The results obtained by PAYEN show the amount of gluten to be from nine to twenty-two per cent.; and during his investigation he discovered the interesting fact, that the quantity of gluten diminishes towards the heart of the seed. From this the conclusion follows, that the part of the grain in immediate contact with the integumental coating, being richest in this principle, is more nourishing as food than any other portion of the wheat grain. **FURSTENBERG** found corresponding results when analysing wheat bran: it contained—

Flour, Organic		Gluten,..........	10·84	12·44
		Albumen,........	1·60	
		Starch,..........	22·66	41·06
		Gum,............	5·28	
		Oil or fat,.......	2·82	
		Water,..........	10·30	
Husk	Organic, or Ligneous matter,............			43·98
	Inorganic	Chloride of potassium,........		0·23
		Sulphate of potassa,..........		0·24
		Phosphate of magnesia,.......		0·93
		Carbonate of lime,...........		0·37
		Silica,.....................		0·75
				100·00

The older chemists ascertained the amount of gluten, by mechanical washing, to be from eight to twenty-four per cent., and the starch from sixty-six to sixty-seven per cent.

Could the operations of the miller be brought to that state of perfection which would insure the separation of the husks, a flour containing thirty per cent. of gluten and albumen—a quantity two-fifths to one-half greater than the yield from ordinary flour—would be obtained. From this it is evident that a great waste of valuable ingredients is incurred by the present process of grinding, by leaving the most nutritive part of the food in the bran, which is composed of—

	Per cent.
Water,................................	13·1
Albumen—coagulated,..................	19·3
Oil,....................................	4·7
Husk and a little starch,.................	55·6
Saline matter—ash,.....................	7·3
	100·0

Considerably more oil is found in the husk than in the interior of the grain, as the table appended shows:

	Oil per cent.
Fine flour,............................	1·05
Boxings,..............................	2·36
Pollard or sharps,.....................	3·56
Bran,.................................	3·25

Starch is a substance present in considerable quantities in wheat flour, and indeed in all the cereals; it deposits from the solution obtained on washing the dough, as before noticed, with water. Some time is allowed for the starch to separate completely, when it forms a concrete granular cake on the bottom of the vessel. It is a substance of considerable importance in maintaining the proper heat of the body. Besides starch, albumen, casein, and oil, as already mentioned, are found in the aqueous extract, as also some gum and sugar. To obtain them, the liquid is filtered from the starch and boiled; the albumen by this treatment coagulates, and may be removed by filtration; on evaporating the filtrate to dryness in a water-bath, a residue remains containing the casein, oil, and sugar; if this solid be treated with boiling alcohol, the casein or mucin is dissolved, and as the solution cools, it separates in the form of white flocculi. It may likewise be obtained by treating the liquid with a little acetic acid, which throws down the casein; the oil is removed as above.

It remains now to consider the sugar in flour. Some investigators have maintained that sugar is present in ripe corn; MITSCHERLICH, KROCKER, and others, contend that no sugar whatever is contained in the ripe grain, but that, during the time when the analysis is being performed, a certain portion of this body is generated by the action of the air, and the influence of the reagents upon the starch. This is more probable from the fact, that lime-water extracts no sugar from the mass, although sugar is much more soluble in this menstruum than in water. It was found, however, that a little gum had been taken up.

From the foregoing, the organic composition of flour is easily understood; and here it will be proper to say a few words on the manner of assimilating the food, or each of the two classes of bodies constituting the flour, to give an idea how one class serves as the general producers or maintainers of the proper heat of the body, while the other is destined for its support. The ultimate elements of the first class are three—carbon, hydrogen, and oxygen—in variable proportions; in some substances the oxygen and hydrogen are so proportioned as to be capable of forming water; in others, the oxygen is present in larger quantities than is required for the production of water with the hydrogen; while a third order is so constituted, that the carbon and hydrogen, compared with the oxygen, are in considerable excess. To the first order of these three divisions, belong—

Starch, the composition	of which is		$C_{12}\,H_{10}\,O_{10}$
Cane sugar,	"	"	$C_{12}\,H_{11}\,O_{11}$
Grape sugar,	"	"	$C_{12}\,H_{14}\,O_{14}$
Milk sugar,	"	"	$C_{12}\,H_{12}\,O_{12}$
Gum,	"	"	$C_{12}\,H_{11}\,O_{11}$

The second order includes those organic compounds which are sometimes found in vegetal substances, as

Tartaric acid, composed of	$C_8\,H_4\,O_{10}$ or $C_4\,H_2\,O_5$
Malic acid,	"	$C_8\,H_4\,O_8$ or $C_4\,H_2\,O_4$

and many similar ones. The third order contains all the fatty and nitrogenous bodies, both animal and vegetal, which are met with, forming a constituent of the food.

It has been shown that all those matters in the food undergo a chemical change, by which water is formed from the combination of their oxygen and hydrogen; while their carbon is carried away into the blood, and thence to the lungs, where it unites with the oxygen of the air inhaled during respiration, forming carbonic acid, a fact corroborated by the continual exhalation of this gas from the lungs of every animal. It is well known that the combination of oxygen and hydrogen, in certain proportions, produces a very high temperature, and the effect of the oxidation of carbonaceous bodies is familiar to every one in the action of burning coals, or in consuming a wax taper; namely, that heat and light are simultaneously produced.

Precisely the same change occurs in the body, though in a less degree, for Providence has so arranged the mechanism of living creatures, that the consumption of their food does not take place in larger quantities than is necessary to maintain the frame at a proper degree of heat—a process most admirably regulated by the decomposition of the blood when it reaches the lungs.

The non-nitrogenous matters of the first order, namely, the starch, oil, and gum, are present in wheat to a large extent; and their utility is as just described. Nitrogenous bodies are, animal and vegetal albumen, fibrin and gelatin, legumin and casein, all of which are nearly allied in their chemical composition, as the following table from KNAPP shows:—

	Centesimally displayed.					
	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Phosphorus.	Oxygen.
Vegetal albumen,....................	54·86	7·28	15·88	0·88	21·10	
Animal albumen,....................	54·42	7·22	15·38	1·43	21·55	
Vegetal fibrin,....................	54·03	7·23	15·74	—	23·00	—
Animal fibrin,....................	54.44	6·99	15·82	1·32	21.43	
Legumin,....................	54·59	7·37	15·78	0·49	21·77	
Vegetal gelatin,....................	54·96	7·17	15·80	0·72	—	21·35
Casein,....................	54·71	7·21	15·70	0·95	—	21·43

It is evident from the identity of composition, as seen here in the constituents of flesh, and similar bodies of vegetal origin, that only a slight elaboration on the part of the digestive organs is required to assimilate such substances from the vegetal food.

In those parts of flour already studied, nothing inorganic has been alluded to, and had the flour no other constituents but those mentioned, it would be ill adapted to support animal life. Animals are, materially viewed, composed of flesh and bone, or organic and inorganic elements, each of which is indispensably and mutually necessary for the proper development of the body. A similar analogy of composition pervades vegetal bodies; inorganic compounds are required in the formation of various plants and seeds, otherwise they could not exist; and these mineral ingredients in wheat bear the closest resemblance to those in the framework of animals, and are also proportioned to the requirements of the animal existence, as will be seen from the subjoined tabular representation of the inorganic constituents of several varieties of wheat, according to recent analyses performed by different chemists:—

TABLE SHOWING THE COMPOSITION OF THE ASHES OF WHEAT, ACCORDING TO RECENT ANALYSES.

Plants, or parts of plants.		Ashes in 100 parts of crop as taken from ground.	Ashes in dry plants, when all the water is artificially removed.	Potassa.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Peroxide of iron.	Chloride of sodium.	Locality of plant.	Analyst.
Wheat of Foreign growth.	Grain, red,.....	—	—	21·87	15·75	9·60	1·93	49·32	0·17	—	1·96	—	Giessen.	Will and Fresenius
	Grain, white, ..	—	—	33·84	—	13·54	3·09	49·21	—	—	0·31	—	Giessen.	”
	” ..	—	—	25·90	0·44	6·27	1·92	60·39	—	3·37	1·33	—	Leipsic.	Schmidt.
	” ..	—	—	6·43	27·79	12·98	3·91	46·14	0·27	0·42	0·50	—	[1]Holland.	Bichon.
	” ..	—	—	24·17	10·34	13·57	3·01	45·53	—	1·91	0·52	—	Solz, Hesse-Cassel.	Thon.
	” ..	—	—	30·12	—	16·26	3·00	48·30	1·01	1·31	—	—	Bechelbronn, Alsace.	Boussingault.
	” ..	1·55	1·74	32·39	2·32	13·94	3·47	43·47	0·35	3·05	0·97	—	France.	Way and Ogston.
	” ..	1·50	1·68	30·30	1·00	14·28	3·17	45·80	—	4·48	0·89	—	Odessa.	“
	” ..	1·7	1·88	35·77	9·06	14·09	2·05	34·44	0·24	4·00	—	—	Adrianople.	“
	” ..	1·97	2·19	36·60	0·53	11·12	4·34	41·03	0·18	4·97	1·18	—	Egypt.	“
Hopeton wheat, grown in England.	” ..	1·81	2·05	33·15	—	12·71	3·20	47·00	0·24	2·84	0·60	—	[2]Cirencester.	“
	” ..	1·51	1·69	33·00	2·07	13·99	2·82	46·18	0·48	1·42	—	—	[3] “	“
	” ..	1·48	1·70	27·06	4·08	13·57	4·29	41·22	1·91	5·91	1·36	—	[4] “	“
	” ..	1·56	1·72	32·24	4·06	10·94	2·06	45·73	0·32	2·28	2·04	0·27	[5]Dorset.	“
	” ..	1·63	1·84	29·92	6·08	12·43	1·83	45·30	0·59	4·43	1·76	0·64	[6] “	“
	” ..	1·61	1·81	36·43	4·62	13·26	1·32	39·97	0·15	4·23	—	—	[7]Gloucestershire.	“
	” ..	1·63	1·81	32·05	3·38	9·32	4·43	47·33	—	3·05	0·35	—	[8] “	“
	” ..	1·71	1·94	34·51	1·87	11·69	1·80	43·98	0·21	5·63	0·29	—	[9] “	“
	” ..	1·69	1·92	30·32	0·07	12·38	2·51	49·22	0·18	3·60	0·08	1·60	[10] “	“
	” ..	1·76	2·01	32·14	2·14	9·67	8·21	44·44	—	3·29	0·08	—	[11] “	“
Red-straw white wheat, grown in England.	” ..	1·70	1·91	31·00	2·54	9·53	1·45	40·91	0·08	9·71	3·34	0·34	[12]Sutton Waldron.	“
	” ..	1·72	1·95	29·75	0·64	13·75	3·27	49·58	0·60	2·14	0·23	—	[13]Gloucestershire.	“
	” ..	1·73	1·97	29·91	1·87	14·05	3·39	47·44	—	2·63	0·67	—	[14] “	“
	” ..	1·61	1·81	30·13	1·25	11·46	6·87	47·38	0·07	2·76	0·07	—	[15] “	“
	” ..	1·60	1·80	30·02	3·82	13·39	1·15	46·79	—	3·89	0·91	—	[6] “	“
	” ..	1·90	2·13	29·17	2·20	14·22	5·05	46·61	0·44	2·17	0·09	—	[17] “	“
	” ..	1·73	1·96	26·70	2·12	12·76	6·78	46·99	0·24	2·05	2·32	—	[18] “	“
Old red Lammas wheat,		1·84	2·10	34·26	4·53	9·56	3·21	40·57	0·32	5·46	2·06	—	[19]Wantage.	“
Spalding wheat,......		1·81	2·05	29·76	5·26	11·06	2·88	48·21	0·11	2·23	0·23	—	[20]Cirencester.	“
Creeping wheat,......		1·73	1·95	31·18	2·42	12·35	1·50	46·49	0·61	5·20	0·22	—	[21]Hackness.	“
” ..		1·65	1·85	28·89	1·40	13·06	6·76	45·64	1·55	2·55	0·11	—	[22] “	“
” ..		1·71	1·91	30·94	1·28	12·74	3·72	48·53	—	1·34	1·40	—	[23] “	“
Mean of the 32 analyses		1·67	1·93	29·97	3·90	12·30	3·40	46·00	0·33	3·35	0·79	0·90	“	“

REMARKS.

1. This wheat being grown near the sea, part of the potassa is substituted by soda.
2. Grown on calcareous stone-brash on the oolite.
3. Grown on calcareous brash and clay.
4. The seed from which the two previous specimens were grown.
5. Loamy soil, on the clay below the chalk.
6. Calcareous soil.
7. Siliceous soil lying on limestone.
8. Clayey soil on the Silurian rocks.
9. Sandy soil on the Silurian rocks.
10. Clayey soil on the Silurian rocks.
11. Sandy soil on old red sandstone.
12. Loamy soil on the green-sand
13. Sandy loam on the old red sandstone.
14. Do. do
15. Calcareous soil on the mountain limestone.
16. Clayey loam on Ludlow rock. (?)
17. Sandy calcareous soil—Silurian.
18. Calcareous clay on magnesian limestone.
19. Very calcareous soil on the chalk.
20. Calcareous stone-brash; great oolite.
21. Soil, clayey sand.
22. Do. do.
23. Soil, calcareous rubble, Oxford clay.

When wheat grain is incinerated, the amount of the ash remaining is about two and a half per cent. from the dry grain, and only two per cent. is obtained when the grain is fresh; of this residuary ash, the preceding table shows the composition in a hundred parts. The apparent irregularity observed in the composition of the ash from various samples, is occasioned by the well-known property of plants, of assimilating different but analogous constituents from the soil, when the true body peculiar to the grain is wanting, either through exhaustion of the soil or otherwise.

By recent analyses, the proportionate quantities of gluten, albumen, starch, fibrin, *et cetera*, in wheat, is exhibited in the annexed, the grain being dried at 212° F

	Wheat from Hohenheim.			Triticum monococcum from Giessen.	Wheat from Vienna.		
	Talavera.	Whittington.	Sandomierz.		No 1.	No. 2.	No. 3.
Gluten and albumen,	16·52	17·09	17·15	13·20	19·15	13·53	21·93
Starch,	56·25	52·45	53·37	54·63	65·68	67·17	57·45
Fibrin, gum, sugar,	24·53	26·53	25·52	29·89	14·09	18·20	20·58
Ash,	2·80	3·13	2·40	2·10	0·70	0·66	1·11
	100·10	99·20	98·44	99·82	99·62	99·56	101·07
Per centage of moisture in the grain,	15·43	13·93	15·48	14·40	13·83	13·65	12·73

The following are the results of the recent analyses of wheat by Peligot:—

	No. 1. White Flemish wheat. 1841.	No 2. Hardy wheat 1843.	No 3. Touselle blanch from Provence.—1842.	No 4. Odessa wheat Poland.	No 5. Blé Herisson. 1842.	No 6. Poulard roux. 1840.	No 7. Poulard bleu Conique 1844.	No. 8. Poulard bleu Conique. Very dry year—1846	No. 9. Mitadin du Midi.	No. 10. Polish wheat. 1844.	No. 11. Hungarian wheat. 1845.	No 12. Egyptian wheat	No 13. Spanish wheat.	No. 14 Tanga rock wheat.
Water,	14·6	13·6	14·6	15·2	13·2	13·9	14·4	13·2	13·6	13·2	14·5	13·5	15·2	14·8
Fatty matters,	1·0	1·1	1·3	1·5	1·2	1·0	1·0	1·2	1·1	1·5	1·1	1·1	1·8	1·9
Nitrogenous matter insoluble in water,	8·3	10·5	8·1	12·7	10·0	8·7	13·8	16·7	14·4	19·8	11·8	19·1	8·9	12·2
Soluble nitrogenous matter—albumen,	2·4	2·0	1·8	1·6	1·7	1·9	1·8	1·4	1·6	1·7	1·6	1·5	1·8	1·4
Soluble non-nitrogenous matter—dextrin,	9·2	10·5	8·1	6·3	6·8	7·8	7·2	5·9	6·4	6·8	5·4	6·0	7·3	7·9
Starch,	62·7	60·8	66·1	61·3	67·1	66·7	59·9	59·7	59·8	55·1	65·6	58·8	63·6	57·9
Cellulose,	1·8	1·5	—	—	—	—	1·5	—	1·4	—	—	—	—	2·3
Saline matter,	—	—	—	1·4	—	—	1·9	1·9	1·7	1·9	—	—	1·4	1·6

The cellulose and ashes, or saline ingredients, are to be deducted from numbers 3, 5, 6, 11, 12, and cellulose only from numbers 4, 8, 10, and 13.—*Knapp.*

Having thus far dwelt in detail upon wheat, on account of its greater importance in bread-making, it will be necessary to give a short sketch of the other cereals, which are also used as food in the form of bread. These are Rye, Barley, Oats, Indian corn, Rice, *et cetera.*

Rye.—This grain, on account of the similarity which it bears to wheat in its physical properties, will form the subject immediately following. Rye is the seed of the *Secale cereale*, resembling wheat in form, but rather elongated. Its cultivation in this country is not carried on to any great extent, but it forms the staple tillage in the Northern European provinces, where the soil, being arenaceous, is well adapted for its production; hence, as Thäer well observes, it is the most precious gift of the Almighty to the inhabitants of sandy and sterile districts; without it, many countries would have been destitute of the means of existence for the human race.

This cereal in its cultivation is subject to many casualties, which partially, or even wholly, prevent the formation of the grain; among these the *ergot* is most destructive.

In an agricultural point of view, very little has been done towards gaining a knowledge of the nature of this substance, and the treatment which affects its growth. Many consider it as a morbid alteration of the *ovarium* of the grain, caused by the puncture of an insect of the genus *musca*, and which deposits a very dark-colored liquid. Some toxicologists rank the ergot of rye among narcotico-acrid poisons: others regard it as a poison *sui generis.* Its chronic effects have occasionally been witnessed on the Continent in an epidemic form, and they have, in some instances, been distinctly traced to its admixture with rye bread. Bonjean knew of two cases in which spontaneous gangrene was induced by bread containing this deleterious substance, which, it is well known, is extensively employed by accoucheurs to aid, and, indeed, to bring on parturition.

When rye is ground, it produces a flour like that of wheat, but considerably darker in color. The reason of this seems to be, that the husk of the grain is more tenacious of the floury parts than that of wheat, and consequently it is carried through in the flour; but the grey tint which the flour possesses may arise from various other causes, such as the grain being partially blighted, *et cetera.* The analysis of rye flour is conducted in a similar manner to that of wheat flour. On washing with water the pasty mass of rye flour, however, no residue remains, as it is entirely carried off mechanically in the solution; hence, the gluten of rye flour cannot be removed from the starch, as is the case with that of wheat. The dissimilarity of these grains in respect to the behavior of their flour with water, seems to depend upon the different nature of their gluten; for, according to **Heldt**, the gluten of rye contains very little fibrin, but a nitrogenous substance, which he names vegetal gelatin.

Since the composition of rye flour, and indeed that of the other cereals, is nearly allied to the flour of wheat, though often different in the proportions, it will be unnecessary to enter into minutiæ with regard to them. An analysis of rye, however, is given which cannot fail to be interesting, as it shows the comparative nourishing power of this grain:—

	Rye flour.			Rye and bran.		
	Einhot.	Greif.	Boussingault.	Flour.	Furstenberg.	Bran.
Gluten,	9·48	12·8	10·5	3·96	Organic matter,	6·18
Albumen,	3·28	3·0		3·34	Chloride of potassium,	0·01
Starch,	61·07	58·8	64·0	65·32	Phosphate of magnesia,	0·39
Sugar,	3·28	10·4	3·0	—	Silica,	0·12
Gum,	11·09	7·2	11·0	3·78		
Woody fibre,	6·38	—	6·0	—		6·70
			Fat.		Water,	14·98
Acid unexamined, loss,	5·62	7·8	3·5	1·92	Total constituents of the flour,	78·32
	100·20	100·0	98·0	78·32		100·00

More accurate results may be calculated as follows, from the elementary analysis of **Horsford** and **Krocker**:—

	Dried at 212° Fahr.					
	Rye flour from Vienna.		Rye flour from Hohenheim.		Buck-wheat flour from Vienna.	Tartarian buck-wheat from Hohenheim.
	No. 1.	No. 2.	Schilf.	Standen.		
Gluten and albumen,	11·92	18·69	17·73	15·76	6·88	9·94
Starch,	60·91	54·48	45·09	47·42	65·05	44·12
Woody fibre, gum, sugar,	24·74	24·49	35·77	35·25	26·47	46·26
Ash,	1·33	1·07	2·43	2·37	1·09	2·30
	98·90	98·73	101·02	100·80	99·49	102·62
Moisture in fresh substance,	13·78	14·68	13·94	13·82	15·12	14·19

The inorganic constituents of the ashes of rye are—

	Rye.		
	1. From Giessen	2. From Cleves.	3. Kidderminster.
Potassa,	31·89	11·43	33·83
Soda,	4·33	18·89	0·39
Lime,	2·84	7·05	2·61
Magnesia,	9·86	10·57	12·81
Sesquioxide of iron,	0·80	1·90	1·04
Phosphoric acid,	46·03	57·81	39·92
Chloride of sodium,	trace	—	—
Silica,	1·42	0·69	9·22
Sulphuric acid,	0·17	0·51	0·18
Charcoal, sand, &c.,	2·66	—	—
	100·00	—	100·00

The first and second samples were analysed by **Will**, **Fresenius**, and **Bichon**, and the third was examined by **Way** and **Ogston**.

Barley.—The barley mostly cultivated in Great Britain is the species known as *Hordeum distichon*, or two-eared barley. As met with in the market, the seeds are usually enveloped in their *patee* or husk; stripped of this it forms *Scotch barley*, and when the latter is rounded by peculiar means, it bears the name of *pearl barley*.

The proportion of nitrogenized matter in barley is much less than in wheat; therefore, the crude gluten is rather deficient, so much so, that very little remains upon washing the dough with water. The annexed analyses of this grain by **Einhof** and **Boussingault**, show the relative proportions of water, husk, and flour, in a hundred parts of the grain:—

	Water.	Bran.	Flour.	
Common barley,	11·0	19·0	70·0	Einhof.
Naked barley,	10·0	17·0	73·0	"
Barley,	13·0	18·0	69·0	Boussingault.

Barley contains about 6·24 per cent. of gluten and albumen, and 69·5 of starch, gum, and sugar. **Fromberg** gives the relative proportion of nitrogenous matter in hard and soft barley, which he calculated from the nitrogen obtained, as follows:—

Soft, or malting barley,	10·93
Flinty, or hard barley,	8·03

Oats.—Another of the cereals, and to which reference has been made, is the oat, a plant extensively cultivated in this kingdom. There are several varieties; that which is prepared in this country is the seed known as the *Avena sativa*. The oat is a seed different in appearance and composition from those grains already spoken of, though the same substances are peculiar to all of them. It is of an elongated conical shape, and is enclosed in a thick husk, deprived of which it constitutes what are termed *groats;* these crushed, produce what is known as *embden groats*, and when finely ground, oat flour or meal of a yellowish white color results; this does not form a dough or paste with water like wheat flour, nevertheless it contains a large amount of nitrogenous matter, which exists in the form of a peculiar body, *avenin*, analogous to soluble casein; it is obtained in the same way as the casein, by precipitating the liquor by acetic acid.

The annexed analyses of oats give the relative amount of water, flour, and bran, in this grain:—

	Water.	Flour.	Bran.
Oats,	—	66	34
„	21	62	17

Norton gives the average analysis of eight samples of Scotch oats which he examined, in the annexed numbers; namely, grain, 76·28; and husk, 23·68. The maximum of husk in his analyses was 28·2, and the minimum, 22·0.

The composition of the French oat, including the husk, according to BOUSSINGAULT, is as follows:—

	Centesimally represented.
Starch,	46·1
Gluten-avenin, albumen,	13·7
Oil,	6·7
Sugar,	6·0
Gum,	3·8
Husk-ash and loss,	23·7
	100·0

Previous to this analysis the meal was dried at 230° Fahr., and the loss of water was found to be 20·8 per cent. Gluten-avenin resembles casein, and is thrown down by acetic acid from an aqueous solution of oatmeal.

The four analyses of Scotch oats following, exhibit a fair average composition of this grain; the analyses were made, exclusive of husk, by NORTON and FROMBERG:—

		Norton Hopeton oats, Northumberland.	Fromberg. Hopeton oats, Ayrshire.	Fromberg. Hopeton oats, Ayrshire.	Norton. Potato oats, Northumberland
Starch,		65·24	64·80	64·79	65·60
Sugar,		4·51	2·58	2·09	0·80
Gum,		2·10	2·41	2·12	2·28
Oil,		5·44	6·97	6·41	7·38
Avenin,	Protein compounds,	15·76	16·26	17·72	16·29
Albumen,		0·46	1·29	1·76	2·17
Gluten,		2·47	1·46	1·33	1·45
Epidermis.		1·18	2·39	2·84	2·28
Alkaline salts and loss,		2·84	1·84	0·94	1·75
		100·00	100·00	100·00	100·00

From the preceding analyses, it appears that the oat is very rich in oily matters and protein. NORTON gives the nitrogen and protein compounds in nine samples of oats, as under:—

	Hopeton oats.			Potato oats.		Oats from Barnbarroch, Wigtonshire.			Imperial oats, New York, U.S.
Nitrogen,	2·19	2·35	2·28	2·76	2·82	2·89	5·51	2·49	3·00
Protein compounds,	14·00	14·78	14·04	17·36	17·77	18·24	22·01	15·66	18·86

The relative proportions of nitrogen and protein compounds in the husk, grain, and whole oats are annexed:—

	Husk.
Nitrogen,	0·30
Protein compounds,	1·88
	Grain.
Nitrogen,	2·82
Protein compounds,	17·77
	Whole oat.
Nitrogen,	2·18
Protein compounds,	13·72

From the earlier analyses of oats and barley, it would be inferred that the latter contains a maximum of six per cent. of albumen and gluten, and a minimum under three per cent.; oats, in like manner, yield, according to those analysts, from three to six per cent. The recent investigations performed, relative to this subject, by Professors KROCKER, HORSFORD, and THOMSON, give an illustration of the rapid advances made by science during the last fifty years, and afford results which are strangely at variance with those of former times, as the subjoined table indicates:—

ANALYSES OF BARLEY AND OATS BY KROCKER, HORSFORD, AND THOMSON, DRIED AT 212° FAHR.

	Krocker and Horsford.		Krocker and Horsford.		Thomson.
	Winter barley, Hohenheim.	Jerusalem barley, Hohenheim.	Kamschatka oats, Hohenheim.	White oats, Hohenheim.	Barley, Scotland.
Gluten and albumen,	17·70	14·72	17·99	12·17	15·24
Starch,	38·31	42·34	37·41	84·74	39·86
Husk, gum, sugar,	42·33	42·46	45·67		46·19
Ash,	5·52	2·84	4·14	3·09	3·26
Moisture in the grain,	13·80	16·79	12·94	9·46	12·71

Those inorganic compounds which are necessary for the production of bone and the other inorganic parts of the animal body, are supplied by the oat. The following analyses of the ashes of oats by Messrs. WAY and OGSTON, demonstrate this point:—

ANALYSES OF THE ASH OF OATS BY MESSRS. WAY AND OGSTON.

	Hopeton oats. Grain.	Potato oats. Grain.	Polish oats. Grain.	Polish oats. Grain.	Unknown. Grain.
Potassa,	17·80	19·70	24·30	16·35	13·97
Soda,	3·84	1·35	3·84	5·27	1·50
Lime,	3·54	1·31	3·54	8·35	4·22
Magnesia,	7·33	8·25	7·33	5·90	8·82
Sesquioxide of iron,	0·49	0·27	0·69	0·09	0·36
Sulphuric acid,	1·10	0·10	1·74	4·01	0·13
Silica,	38·48	50·03	41·86	43·20	49·44
Carbonic acid,	—	—	—	0·59	—
Phosphoric acid,	26·46	18·87	14·49	16·19	21·53
Chloride of sodium,	0·92	0·07	0·45	—	—
Loss,	0·04	0·05	1·76	0·05	0·03
	100·00	100·00	100·00	100·00	100·00
Per centage of ash in the dry substance,	2·50	2·73	2·97	3·80	3·12
Per centage of ash in the fresh substance,	2·27	2·45	2·65	3·31	2·75

INDIAN CORN.—Indian corn and rice are two other vegetal products used in the manufacture of bread, and for that reason are deserving of a cursory notice. Indian corn, as it comes to the market, is of a yellowish color, but some varieties are white; the shape of the grain is somewhat rectangular, but broader and thicker at the top; the nutritious portions are enveloped in a very thick covering. The corn does not thrive in this country, but grows luxuriantly on the American soil, as well as in southern Germany, and other warm climates.

When the dough of Indian corn is washed with water, like that of wheat, a glutinous residue is left, different, however, from the gluten of wheat, and characterized by its solubility in alcohol, and, therefore, allied to vegetal gelatin; Bizio, nevertheless, states that spirit dissolves no more than two-thirds of this substance; he obtained 5·5 per cent. of gluten. The following elementary analyses are different from the preceding in the amount of nutritious matters:—

	Indian meal from Hohenheim.	Indian meal from Polenta, Vienna.
Gluten and albumen,	14·66	13·65
Starch,	66·34	77·74
Husk, sugar, gum, fat,	18·18	7·16
Ash,	1·92	0·86
Water in fresh substance,	14·96	13·36

Indian corn contains more fatty matter than any other grain, and as much as four and a half per cent. of a yellow thick fluid oil.

Maize, or Indian corn, yielded fourteen per cent. of water, and the dried grain upon analysis gave to Payen—

	Centesimally.
Husk,	5·9
Gluten,	12·3
Starch,	71·2
Sugar and gum,	0·4
Fatty matter,	9·0
Saline matter, or ash,	1·2
	100·0

The ash of this grain is composed of the following:—

	Grown in the U. States. Fromberg.	Bechelbronn Letellier.
Potassa,	26·63	30·8
Soda,	7·54	
Lime,	1·59	1·3
Magnesia,	15·44	17·0
Phosphoric acid,	39·65	50·0
Sulphuric acid,	5·54	—
Silica,	2·09	0·8
Sesquioxide of iron,	0·60	—
Loss,	0·92	0·1
	100·00	100·0

Rice.—Two specimens of rice, examined by D'Arcet and Payen, the one from Lombardy, and the other from Carolina, contained thirteen and a half per cent. of moisture, and twelve of nitrogenous matter; the method of analysis pursued, however, was calculated to give too much of the latter.

Johnston found the composition of a species of unhusked rice to be—

Husk,	20·91
Grain,	79·09
	100·00

Five varieties of rice, freed from husk, gave respectively the annexed proportions of water and ash:—

	Water.	Ash.
Madras rice,	13·5	0·85
Bengal rice,	13·1	0·45
Patna rice,	13·1	0·36
Carolina rice,	13·0	0·33
Carolina rice flour,	14·6	0·35

According to Payen, dry rice contains—

	Centesimally.
Starch,	86·9
Gluten, *et cetera*,	7·5
Fatty matter,	0·8
Sugar and gum,	0·5
Epidermis,	3·4
Saline matter—ash,	0·9
	100·0

The following analysis of the inorganic constituents of rice, shows the nature of the mineral substances contained in this grain:—

	Rice grain from Bechelbronn.	Husk.
Potassa,	18·48	1·60
Soda,	10·67	1·58
Magnesia,	11·69	1·96
Lime,	1·27	1·01
Phosphoric acid,	53·36	1·86
Sulphuric acid,	—	0·92
Silica,	3·35	89·71
Sesquioxide of iron,	0·45	0·54
	99·27	99·18

Rice contains less fatty matter than any other grain, and, as with most of the cereals described, the greater portion is found in the husk.

Preparation of the Corn.—The nature and quality of the cereals principally employed in the manufacture of bread having thus been explained, it may be interesting to follow the wheat from its marketable state, through the successive operations to which it is submitted, until it emerges from the baker's oven.

Although the cultivation of grain may be traced from the earliest date, yet the methods by which it was prepared into food are not fully known. Bread is noticed very early in Holy Writ, the first mention of it being made when Adam transgressed the Divine command.

Waiving all historical details, the various stages of preparing the corn deserve attention, the first operation being the cleaning of the grain.

Cleaning and Winnowing.—In the more lately constructed steam mills, whether they be French, American, or English, the machinery for cleaning the grain is generally of three kinds; the first consists of a series of sieves, which remove the foreign materials—stones, shells, *et cetera*—from the grain and finer impurities.

The second apparatus is a kind of mill-work, and removes the husky parts of the grain; the runner is so far elevated, that none of the grain is reduced to powder during the action.

The third separates sand, dust, or any other dirt from the grain by attrition; to effect which, a cylinder lined with brushes is made to revolve, and these, by scrubbing the grain against the cylindrical, file-like surface of the case, effectually detach all the lighter bodies. Having disintegrated the light dirt, it is afterwards removed completely by a winnowing-fan, worked by the machinery.

Figs. 221 and 222, are drawings of an apparatus for cleaning, winnowing, and separating different kinds of grain at one process, invented by MM. JEROME, BROTHERS, of Amiens, and lately introduced into use in several districts of France. Fig. 221 is a front exterior view; and Fig. 222 a vertical section, made through the axis of the apparatus. The different working parts of this machine are so arranged as to occupy little space, and to effect the various operations in a steady and uniform manner, requiring but little motive power. The frame, in which the whole machinery is enclosed, consists of two cast-iron cases, A. The corn to be cleaned and sifted is first thrown into a hopper, B, from whence it falls into the riddle, C, by which the straws and all other foreign bodies larger than the grain are removed. This riddling-box receives a jerking motion directly from a cam, fixed at the extremity of the horizontal iron shaft, E, which carries the vanes of what may be termed the *thrasher*. The riddled corn falls by the inclined sluice, I, towards the lower part of the fixed drum, G, formed of rasped sheet-iron, having its rough side inwards, and which, at its opposite ends, is closed with a metal grating, H. The horizontal shaft, E, carries two series of arms, *i i*, to which are attached the wooden vanes, J, and these are in like manner furnished with sheet-iron rasped on the surface, so that, by the rapid rotation communicated to the axis, they beat the corn against the interior of the drum, and raise it, while being subjected to this process of thrashing, to the upper part, whence it proceeds by the channel, K, towards the end of the machine, into the box, L, closed in front by a cover of wire gauze, through which passes the air that is driven by the vanes. All the dust which is thus disengaged from the corn passes from the drum through its various little openings into an exterior case, and is then delivered into a kind of trough, N, which constitutes the lower part of this exterior case. The dust is removed, when desired, by a small door of sheet-iron. The cleaned corn falls from the box, L, into the riddle, O, in proportion as it is winnowed by the air from the vanes, J, which air escapes by the passage, P.

Fig. 221.

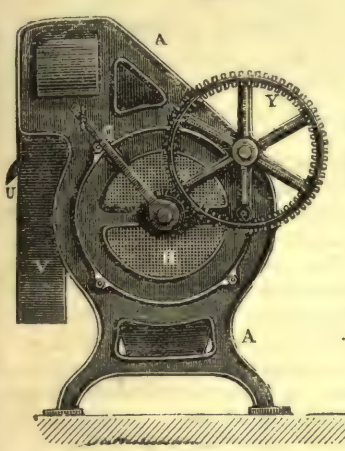
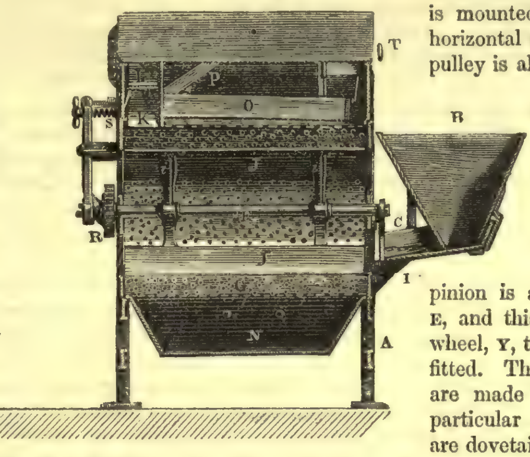


Fig. 222.



This riddle or sifter, which has for its object to separate all the small seeds and dwarf grains from the good corn, receives also, like the first riddle, an oscillating movement, more or less energetic, by means of the lever, Q, which, at its lower extremity, carries a stud that is acted on by the cam, R, fixed near the end of the horizontal shaft, E. A spiral spring, S, the tension of which may be regulated at pleasure, permits, with the aid of an abutting screw, to limit to any required extent the oscillatory movements of the riddle. All the good corn which passes out at the lower end of the riddle is delivered into the inclined sluice, U, from which it may be received into a sack; and all the refuse which has passed through the holes of the sieve descends into the receptacle, V, at the bottom of which is a door for the purpose of removing it when necessary.

When this machine is intended to be fitted to a mill where it may be driven by a constant force, a fixed cast-iron pulley, connected with the main shaft of the machinery, is mounted at the end of the horizontal shaft, E; and a loose pulley is also provided, to allow of interrupting the movement at pleasure. When, on the contrary, the apparatus is intended for a farm, where it is generally driven by the hand, a toothed pinion is applied to the shaft, E, and this gears with a large wheel, Y, to which a handle is fitted. The teeth of this wheel are made of wood, but of a particular construction. They are dovetailed into the iron circumference of the wheel, so as that the wood is surrounded with the metal on three sides. In this way, each of the teeth is much more solidly fixed than by the usual method; and still the important point is attained of having wood in contact with metal, since it is only the projecting part of the teeth of the wheel that is brought into contact with those of the pinion.

The sifting process is effected by a very simple arrangement, which permits of collecting separately grains of different kinds and sizes that have been mixed together—in a word, which performs the part of a *sorter*, while at the same time the work of cleaning is accomplished. This arrangement consists in placing within the riddle several pieces of wire gauze of different degrees of fineness, the one over the other; and making these correspond to the different sizes of the several kinds of grain to be collected. One piece of this gauze may be fitted in the receptacle for the siftings, V; another is connected with the outside of the machine by the sluice, U. The effect produced by this arrangement is as follows:—The mixed grains of rape and poppy-seed, for example, fall on the upper wire sieve, the poppy-seed passes through and falls on the second, while the rape-seed, being larger than the poppy-seed, travels over the upper sieve, and falls out at the end of the riddle into a separate receptacle. The poppy-seed is separated from the refuse siftings by the lower sieve of wire gauze, through which the latter pass and fall into the reservoir, V, while the good grain or corn arrives at the sluice, U, from which it is received into a sack.

Grinding.—Even after the grain is cleaned in this or any similar manner from all those bodies which would injure the quality of the product, a great deal rests upon the management of the grinding. This is of great importance, as, if improperly executed, not only will the product be deteriorated in quality, but diminished in quantity.

In describing this process, a short sketch of the mills now in use will be necessary.

The object of grinding is, the division of the coating or husk, which is, comparatively, indigestible, from the interior part of the grain. As it has been shown that the portion nearest the *shell* is richest in plastic or nitrogenous substances, it is evident that the more completely the finer parts are separated from the integument, the more nutritious will be the flour. In attempting to gain this point, the miller frequently runs into extremes, either reducing the grain to such a minute state of division that the husk passes through the bolter with the flour, or not grinding the grain fine enough, whereby flakes of the most valuable part are thrown away.

Mills, generally speaking, contain three classes of machinery; that for the actual grinding, the hopper which supplies the grain to the stones, and the bolter and its case, where various sieves produce flour of the requisite fineness. In Germany, this set is called a *gänge*. In mills lately constructed, besides the preceding being more complete, various other apparatus are appended.

In noticing the first class of machinery, the millstones claim priority. These are rarely entire, almost always being constructed of several blocks cemented together by gypsum or Portland cement, and surrounded with strong iron bands. Their size varies from three to five, and occasionally seven feet in diameter. The stone should be so hard that it will not readily become smooth, yet not so hard as to render its dressing or grooving difficult. Knapp says, blocks hewn out of the Rhenish lavas are preferable for their hardness and open texture; for, as the stone is abraded, the blisters break, forming a series of cavities bounded by sharp edges, which partially supply the place of artificial grooves. The best millstones in this country are made from a very hard silicious rock, known by the name of *Buhr* or *Burrstone*, and found only, in any quantity, in the vicinity of Paris, and a few other places in France. It is imported into this country as ballast, and sells for about twelve pounds per ton. Its pores are very large, often requiring to be filled with alum and grit, yet, at the same time, it is so durable, that a pair of stones have been known to last, in active operation, for twenty years.

In cutting them, the surfaces of contact are not left smooth, as might be supposed, but are indented to a depth of from a quarter to one-eighth of an inch, in a series of lines diverging from the centre to the circumference. Such grooving is called the *dressing*. If the stones were without the indentations, the grain would only be crushed, in which state it would clag and adhere to them, thus offering a great obstruction to their rotatory motion. In such a case, the portions thrown out, instead of the husk being properly separated, are found so blended together, unless the corn is completely dried, that it is impossible to detach, economically, the valuable parts of the grain. Even if kiln-dried grain was used, the operation could not be conducted with smooth-surfaced stones, on account of the heat which a closer friction occasions in the flour; besides this, a glaze or polish would be given to it, by which its quality would become impaired.

There are various methods of grooving the stones. Figs. 223 and 224 represent the American plan of dressing, which is considered the best. The grooves in the top stone, or runner, are so adapted to the lower or bedstone, that, when motion is communicated to the former, an action takes place between the indentations of both stones, similar to that of shears or scissors. In dressing, the furrows are never made perpendicularly at both sides, but at one side the groove is cut vertically, and the hollowed portion diverges to the straight line at an angle of about 45°. Both stones are grooved in the same manner and direction, but when the runner is afterwards placed in its working position, the course of the stones, as also that of the channels, is reversed, and both the edges meeting in opposition, cut the intermediate grain into fragments; these, in being swept over the *landings*, or smooth spaces of the mill-stones, are ground fine.

Fig. 223.

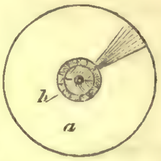
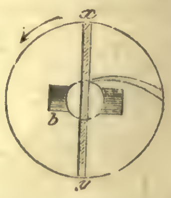


Fig. 224.



Sometimes, instead of the channels being curvilinear, as in the preceding woodcut, they are straight, as in the annexed sketch of the stones of a French power mill—Figs. 225 and 226. A dressing similar to the latter is practised in this country, but the number of long or *master furrows* is generally eight, and the shorter or auxiliary ones twenty-four.

Fig. 225.

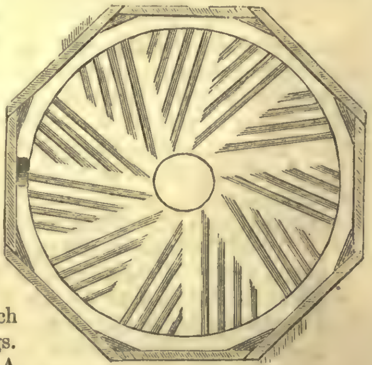
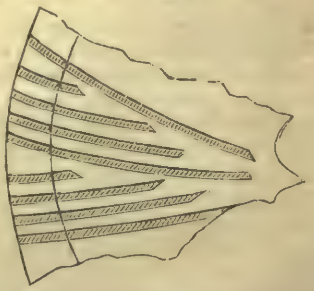


Fig. 226.



In ordinary mills, each stone is, for the most part, dressed differently, the runner invariably having spiral channels from the centre to the circumference, while those of the bedstone are radii. A large diametrical canal is cut in the runner for admitting air. The central circles in these engravings show the spaces through which the spindles pass.

When the stones are again to be dressed, the furrows are reversed, the spiral ones being cut into the bedstone, and the radii into the runner. Figs. 227 and 228 express this arrangement.

Fig. 227.

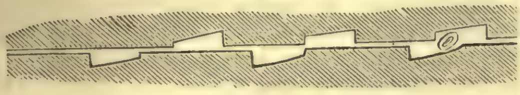
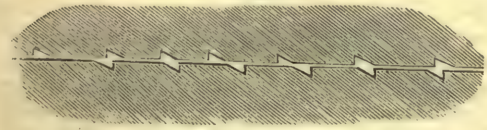


Fig. 228.



The use of the hopper and bolter will be better understood, as reference is made to the general construction and employment of each part of the mill.

They are often differently made, but, excepting the motive power, the same principles are referrible to them all. Wind, water, or steam is generally used, the choice being dependent, to a great extent, upon the favorable or unfavorable position of the mill-house.

Fig. 229

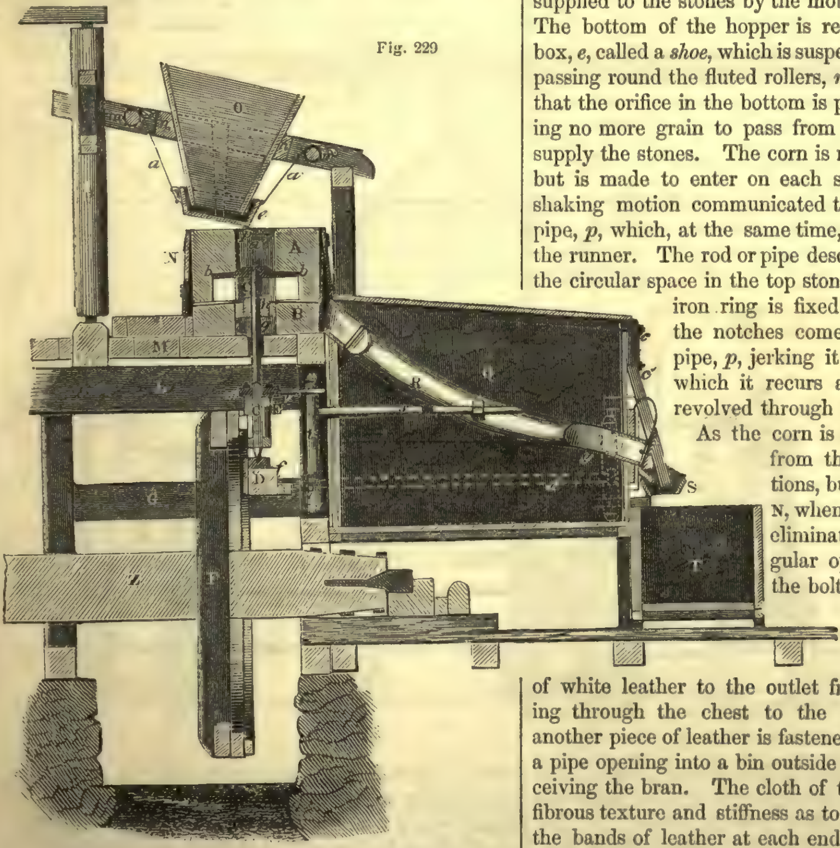


Fig. 229 is a section of a common mill, moved by the action of water upon a wheel of large dimensions, not shown in the engraving.

The shaft from the water-wheel is generally a large beam of wood, represented in the cut by Z; upon this the second or principal wheel, F, is constructed, the cogs of which act upon the fly, E, of the spindle, C, which is an iron bar forming the axis of the stones; its lower end is conical, and rests upon a bed of steel, *f*, which is supported by the beam, D, fixed upon other cross-beams, G and L, forming a kind of leverage, whereby the beam, D, and spindle, C, are depressed or elevated as required. The stones which grind the corn are A and B, the latter being the bedstone, in the middle of which, as at *g*, the iron bar, C, passes through a tightly-fitted packing-box, *h*, to the runner in which it is fastened, by fixing in the circular space cut away—about six or eight inches in diameter—an iron bar, *b b*, having a rectangular hole in the centre, into which the end of the axis, C, exactly fits. This apparatus is called the *ryne*.

A case, N, envelopes both stones, to protect them from dirt, and to prevent the ground material being scattered about by the centrifugal force of the runner. Over that part of the machinery already described, a prismoidal-shaped hopper, O, is supported upon a frame, *n n;* into this box the grain is emptied, whence it is supplied to the stones by the motive power of the mill. The bottom of the hopper is received into a movable box, *e*, called a *shoe*, which is suspended by the cords, *a a*, passing round the fluted rollers, *m m*, in such a manner that the orifice in the bottom is partially closed, allowing no more grain to pass from it than is necessary to supply the stones. The corn is not let in at one place, but is made to enter on each side of the ryne by a shaking motion communicated to the shoe by the iron pipe, *p*, which, at the same time, conducts the grain to the runner. The rod or pipe descends a few inches into the circular space in the top stone, *a′*, where a serrated iron ring is fixed; as the stones turn, the notches come in contact with the pipe, *p*, jerking it out of its position, to which it recurs after the stones have revolved through the arc of a circle.

As the corn is ground, it is expelled from the stones in all directions, but collects in the case, N, whence, however, it is soon eliminated, through a rectangular opening in the case, to the bolter in the flour-box, Q. The sifting is effected by the bag, R, attached by a strip of white leather to the outlet from the case, N, passing through the chest to the opposite end, where another piece of leather is fastened to it, and secured to a pipe opening into a bin outside the flour-box for receiving the bran. The cloth of the bolter is of such a fibrous texture and stiffness as to prevent it collapsing; the bands of leather at each end also assist in keeping it in the proper form. A continual motion is given to this bag in the following manner:—Over the fly, E, of the axis, C C, a triangular piece of iron, *w*, is fixed, which moves with the axis, and as this piece revolves, the angular points come in contact with the finger, *v*, moving it through an arc of from 40° to 45°. The finger being fixed to the cylinder, *t*, causes this also to move, and by its means the rod, *s*, and the bag, R, with which it is connected, are tremulously agitated. In this manner the finer parts of the ground material are sifted through the bolter-cloth; while the coarser flour and bran pass off to the bin, T, or they may be received in the sieve, S, where the coarser parts of the flour are completely removed. An oscillating motion is given to the sieve by the wooden spring, *c c′*, and the spindle, Z, through which the conducting-rod, *d*, passes, in a manner similar to that in which the bag, R, is agitated. The coarser parts are often returned to undergo a second grinding and sifting.

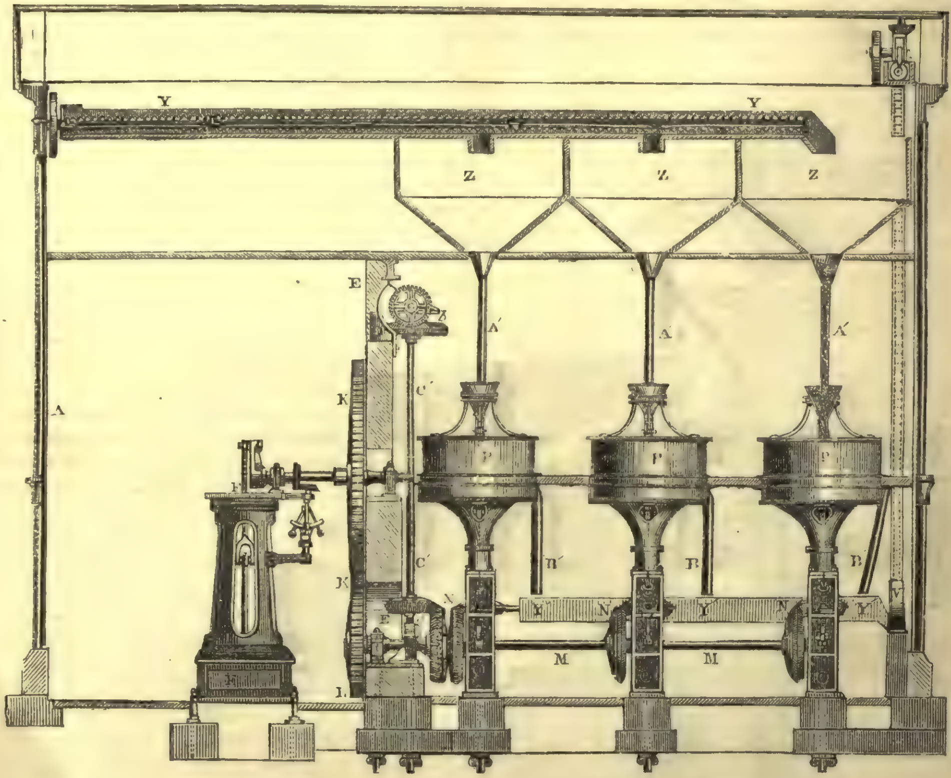
Another ingenious machine for dividing the flour from the bran, and which is more generally used, separates several kinds, according to their state of division, at one operation. It is termed the *dressing machine*, and consists of long, hollow cylinders of wire-gauze, of various degrees of fineness, according to the qualities of flour to be produced, protected on the outside by a framework of longitudinal and circular slips of wood, put at regular distances from each other, the whole being fixed in an inclined position. In the interior a set of brushes revolves, rubbing against the wires, and clearing the meshes from adhering particles.

The entire machine is enclosed in a box, which prevents the escape of floury particles in the form of dust. The cylinders of wire-gauze are so fitted in as to be readily replaced by others, of any requisite size, to suit the fineness of the flour to be separated.

After some time, the meshes of the cylinders get filled with adhering particles of flour, and the brushes also lose much of their effect from the inclination of the bristles, occasioned by being worked in one direction; consequently, the dressing is very imperfectly accomplished. The first difficulty is overcome by means of a strong brush rubbed exteriorly against the wires from time to time; the adhering substance is by this means completely removed. The second fault is obviated by having the brushes so arranged, that they will move in either direction, by which they last a longer time, and work much more effectually.

Fig. 230 represents a plan of the whole mill. E E is the masonry for supporting the driving gear of the machinery; F, the steam-engine; K K is the spur fly-wheel of the engine working into the pinion, L. The main horizontal shaft of the mill is represented by M M, and the level mortise wheels and pinions for driving the stones are seen at N N N; P P P are the millstone cases. There is a passage conducting the grain from the elevator to Y Y, the *creeper*, by which it is distributed into Z Z Z, the garners for feeding the stones. A′ A′ A′ are feeding pipes made of tin plate; B′ B′ B′, pipes by which the flour is withdrawn from the stone cases into Y′ Y′ Y′, the second creeper-box, which con-

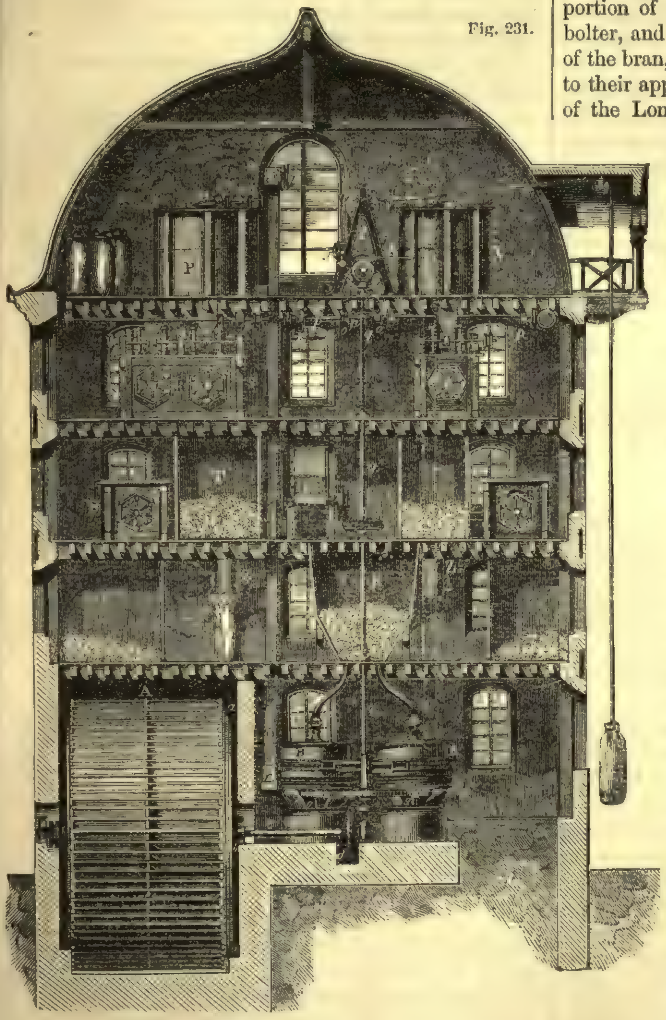
Fig. 230.



ducts it to the second elevator; C′ C′ is the shaft which works the dressing machine by the bevel wheels, *a* and *b*.

Fig. 231 is a sectional view of the interior arrangement of a flour mill for grinding corn, as adopted in France. The motive power is a water-wheel, A, and by means of a spur-wheel, *a*, appended to the axis, and pinions, *b b*, this is made to move the stones, B B. Motion is likewise communicated to the cleansing machine, P, the boulters, R R, *et cetera*, by an upright shaft, *q′ q′ q′*. The corn is cleansed by a winnowing machine, L, before it descends to the hopper, K, from which the stones are supplied. An endless chain of buckets, O O O, raises the flour from the stones to the boulter, *p*, and after undergoing a purifying process here, it descends to the several other machines, R R R, where the various qualities of flour are separated and collected in sacks. The details of the arrangement are too numerous to be fully stated, but the figure above given will be intelligible to every miller.

Fig. 231.



By the common methods, the grain which is ground at one time must be passed through the stones repeatedly, their relative position being altered each time, according to the degree of fineness required. The stones, by continued use, become so much abraded that they would no longer touch the grain if the miller did not, from time to time, regulate their distance by a screw provided for the purpose.

During the first two or three courses of the corn between the stones, the runner is so raised that the grain is only coarsely broken, and this is repeatedly passed through the grinding and dressing apparatus till no more flour is reduced; the residue is bran.

Fine flour of various qualities is obtained from that portion of the grain which flies off as dust from the bolter, and the other parts remaining, already deprived of the bran, are designated by different names, according to their appearance and degree of fineness. In some of the London mills, no less than seven different products are obtained, the relative quantities of which, according to URE, are the following:—

Fine flour	5 bushels	3 pecks.
Seconds	0 "	2 "
Fine middlings	0 "	1 "
Coarse middlings	0 "	0·5 "
Bran	3 "	0 "
Twenty-penny	3 "	0 "
Pollard	2 "	0 "
	14 "	2·5 "

The observations of millers, at different periods, led to the moistening of the grain before grinding, to effect the complete separation of the husk. As the corn generally appears in the market, it is too dry to be ground, or at least, if ground in this state, the husk would be so finely divided that it would pass through the bolter with the fine flour, and communicate a brownish color, which would be very objectionable. To oppose this, the grain is cast into a tank of water to remove the lighter impurities that may be present, which, as they rise to the top, are skimmed off. After draining the excess of water, another portion of dry grain is added to what was moistened, and after the mixture has been left to soak for some time, is submitted to the mill; others have adopted the less laborious plan of sprinkling the grain with the water. Although these methods are serviceable for removing portions of the dust and impurities, and also in assisting to detach the husk more completely, they are, nevertheless, very often injurious to the flour; from being impregnated with a larger quantity of moisture than the grain naturally holds, it becomes mouldy, and, if kept in barrels or sacks, or any other confined place where the moisture is retained, it ferments, and ultimately turns sour.

The flour, as it comes from the stones, is hot, on account of the great friction to which it is subjected, and if allowed to remain at the acquired temperature, *en masse*, it would ultimately become acid, particularly if the grain contained any excess of moisture.

In well-regulated mills, this source of injury is neutralized by immediately conducting the ground material, by means of a chain of buckets, to a spacious floor in the upper part of the building, where it is spread out to cool. This operation is the more needful when the grain is so dry that the husk cannot possibly be detached from the flour in the grinding, unless it be previously moistened.

In consequence of the moistening process, the finest quality of flour imported from America is often found agglutinated into hard musty lumps throughout the cask or sack. MITSCHERLICH and KROCKER, who examined this subject, show that the wheat in which sugar was proved to be absent before sending it to the mill, yielded, after being ground, as much as four per cent.; this transformation of the starch into sugar could not be produced otherwise than through the internal action of the gluten, aided by air and superabundant moisture. When once the action sets in, it quickly passes through the whole heap, if not speedily checked either by cooling or drying the flour. The decomposed starch or sugar, when the mass is left to cool gradually in large heaps, soon enters upon the alcoholic, and sometimes even the acetous fermentation. This action always takes place in the middle of the heap first, and proceeds towards the surface, the air enveloped in the flour, and the heat produced by the transition of the starch to sugar and alcohol, successively favoring the change most in the centre. The affected flour has a gritty feel, not unlike that of gypsum, and, of course, makes very unwholesome bread.

Flour containing only its natural portion of moisture, is the best for stock and exportation. BERGS kept various samples of flour, and found that the second and third qualities, which contained most gluten, were completely spoiled after keeping only nine months, during which no want of care could be alleged as the cause, as the casks were placed in a cool, airy, and dry warehouse.

Many English millers are much opposed to moistening the grain previous to grinding it, and even dry damp grain upon a kiln to deprive it of its acquired humidity; the flour which they obtain, though inferior in color to other varieties, is better adapted for storing and exportation than any other. The American flour is decidedly the whitest brought into the market; this must be owing to their more perfect sifting machinery, and cannot be from the better quality of their grain, as it is universally allowed that English wheat is seldom or never surpassed. The Americans cool their flour very rapidly by means of special machinery, while the English miller leaves it to cool in the sack, on which account it feels gritty to the touch.

The best and most expedient way of securing a flour of the whiteness of the American article, and possessing at the same time the durability of the English, would be to grind the grain slightly moistened—as is the custom with the American millers—and afterwards dry the flour at an incipient heat in properly constructed chambers; the excess of moisture would in this way be expelled, and the husk or bran would be more completely detached from the flour. This method has been tried, in the event of shipping the product to a distance, with very favorable results.

On the whole, English millers obtain a larger bulk of flour than the Americans, but the latter produce as much as four per cent. of the first quality over the English. Bran, as it comes from English mills, only slightly whitens a black cloth, but the American bran retains considerable portions of the matter of the grain attached to it.

The following are data given by KNAPP, showing the proportionate results obtained from the old and new mills; and as this chemist states them to be the mean of six experiments, they may be looked upon as a fair comparison of their merits.

From one hundred pounds of maize were produced in an old mill—

Fine flour,	55	pounds.
Middle flour,	18	"
Black flour,	9	"
Bran,	18	"
	100	

And from the same weight of barley the proportions were—

Fine flour,	40	pounds.
Coarse flour,	20	"
Middle flour,	10	"
Black flour,	5	"
Bran and loss,	25	"
	100	

In a new mill at St. Maur, near Paris, there were obtained from every hundred parts of grain—

72	of flour, first quality,
3	of flour, second quality,
3	of flour, third quality,
7	of coarse bran,
10	of fine bran,
3	of black bran meal,
1	separated by sieves,
1	loss.
100	

In noting the above, however, it should be remembered that the stones wear away considerably in grinding; so much so, that they often require to be dressed in twenty-four hours; the portions worn off as dust are mixed with the flour, and increase the weight of the total yield. By care, this impurity is prevented from mixing with the flour, except at the beginning, for it is chiefly deposited around the bedstone, and the jacket which encloses the grinding apparatus. From repeated experiments, it appears that when good stones are employed, not more than an ounce of stone dust is found in one hundredweight of the product.

Dr. HASSALL gives the following table as the yield of a quarter of wheat—weighing 504 pounds—when ground:—

	Pounds.
Flour,	392
Biscuit, or fine middlings,	10
Toppings, or specks,	8
Best pollard, Turkey pollard, or twenty,	15
Fine pollard,	18
Bran and coarse pollard,	50
Loss sustained by waste in grinding, *et cætera*,	11
	504

FABRICATION OF BREAD.—Practically, it will be seen that if meal or flour be worked up with some water, and dried either spontaneously, or at a very incipient heat, a substance is obtained which binds together with no great degree of firmness; the starch and other matters remain in such a mass unaltered; it is insipid and indigestible. But if the mass be heated throughout for some time at a temperature of 212° Fahr., a change occurs; the starch is rendered soluble, and the whole body becomes firm, dense, and compact; still, however, it is only with difficulty digested. Such is not the baking or cooking process to which the food of the community is subjected at the present day, though in ancient times it was universally practised; even still, in many parts of the world, this method of baking is continued, as in the North of India and Afghanistan: the Jews also make their pascal or unleavened bread in this way; and in preparing sea-biscuit, the method continues, with only slight modifications, almost general. Bread prepared in this manner is merely the dough dried in a peculiar way, with the formation of an outward crust, and the thinner the cakes are made, the more easily is this effected. The density of such bread is much greater than that of the ordinary article, in consequence of all moisture being expelled, and the constituents of the flour being only very slightly different from their original composition, hence it is difficult to masticate; it keeps, however, a much longer time than any other kind, and on this account is admirably adapted for sea stores. If a dough made of flour and water be heated, so as to render the starch soluble, and at the same time produce an exterior crust without passing into the shrunk, glassy, mass of biscuit bread, a food is produced which is easily masticated; and, in consequence of the substance between the crusts being doughy, the extent of surface offered to the saliva in mastication, and the digestive organs, is so large, that it is assimilated with comparative ease, and bad results very seldom follow its use.

A most necessary quality in bread is, that it should be furnished with a thin crust, and have sufficient porosity to present a large surface to the action of the gastric juice; and to insure these qualities various means are adopted. Fatty and oleaginous matters are used to distend the plastic mass, which they effect, as in the formation of the Spanish dough or pie-crust. Leaven, another of the bodies used to make bread possessing a great degree of porosity, is no other than a portion of the ordinary dough left in a warm situation, till fermentation sets in; if left too long under this influence, it becomes first sour, and then putrid. The use of leaven in baking, is to induce the same fermentative action in the fresh flour as is going on in itself, but it should be employed with the greatest caution, for if the acid transformation has commenced in the leaven, it will communicate a disagreeable taste to the bread. Yeast is now almost universally resorted to for effecting the purpose under notice, and has considerable advantages over those previously spoken of, since it confers porosity in a high degree, without generating any disadvantageous property in the loaf. Indeed, the employment of yeast in baking has been productive of the greatest benefit to the trade; so much so, that the rapid improvements of late years in this art may be attributed to it.

Three principal materials are requisite for obtaining good bread, namely, flour or meal, yeast or leaven, and water, with a suitable quantity of salt; various other admixtures have been, and continue to be made, such as milk, butter, or eggs, to confer a greater whiteness and richness on the loaf, but none of the three first mentioned can be omitted under any circumstances.

FERMENTATION.—Panary fermentation, induced by yeast or leaven, is the same as that which takes place in the formation of alcohol, though the action is more limited. It has been shown that sugar is not a constituent of grain, more especially of wheat; though, when the latter is exposed to moisture, this substance is formed in considerable quantities. When the flour is mixed with a proportion of water sufficient to form the dough, the production of sugar becomes more brisk, for the gluten of the flour induces its formation, and the ferment, whether it be leaven or yeast, effects the conversion of this sugar into alcohol and carbonic acid gas to a greater or less degree. The formation of a lump of dough by the use of a ferment and water, will readily demonstrate that not only is a considerable surface exposed to the air, but a volume is also enveloped in the mass; and, as has been shown under ACETIC ACID, alcohol, in contact with air or oxygen, at a slightly elevated temperature, readily passes into vinegar; so, in this case, the decomposition of the spirit follows, if fermentation be prolonged beyond the necessary period. It has been urged that no sugar is produced in the flour during kneading, and that as soon as the small quantity of sugar formed immediately after grinding, as shown in the preceding page, is converted into alcohol, fermentation ceases. The first assertion is not satisfactory, for it will be readily seen that, if flour is mixed with a proportionate quantity of water, and maintained at a temperature of 100° to 120° Fahr., considerable quantities of the starch will be acted upon, in consequence of the property of gluten, like that of diastase, of changing starch into sugar. All the sugar which the gluten of the flour would be available in producing, is not, however, formed in the dough; but the amount is proportionate to the time the flour is left in contact with the water and ferment, before its introduction into the oven.

So far as regards the conversion of the sugar into alcohol, it will scarcely be denied by any person who is at all acquainted with the subject, that the acetous is carried on simultaneously, though incipiently, with the alcoholic fermentation; for, unlike that of the brewer or distiller, where generally an atmosphere of carbonic acid gas excludes communication with oxygen, it is purposely retained in the fermentation of bread, to make the bread porous; hence, the air is always in contact with the dough, to exert its influence in the formation of acid from the alcohol with which it meets; the longer, therefore, the dough is exposed, the larger will the proportion of acetic acid be, and the dough will finally manifest a sour taste. The retention of the carbonic acid and alcohol is the cause of that sponginess which is so desirable in bread; but it will be seen that some portions of the valuable constituents of the flour are destroyed to give existence to them, and so far as the vesicular structure of the dough is concerned, their action is merely mechanical.

Various other compounds eliminating carbonic acid have been tried as substitutes for yeast, but their use is always attended with indifferent success. The reason is evident. When such compounds are decomposed to give the carbonic acid, the action takes place so rapidly that the baker has not time to work his dough as usual, and still retain the gas; and during the short time which he requires to form the loaf, a considerable portion of the elastic fluid is evolved to his loss. It appears, also, that the loaves made by such treatment are full of large cavities, with interposed walls of doughy consistence, unlike bread fermented with yeast, which is so regularly cellular through its entire extent, arising from the carbonic acid and spirit being generated in all parts of the mass of dough. It is a remarkable fact, that a little soap-suds added to the dough arrests fermentation; its action depends upon the absorption of the carbonic acid by the alkali of the soap, forming a carbonate, and the fatty acid of the soap is liberated: both these are antiferments, but besides their arresting the fermentation, the bread is rendered dense by the carbonic acid which is already formed being absorbed, and the tenacity of the dough is further destroyed by softening. Yeast possesses a very disagreeable bitter taste before it is mixed with the flour, but when the loaf is baked no such taste can be detected.

FOWNES has shown that flour and water mixed, and left at the normal temperature of a moderately warm room, arrives at the usual state necessary to induce fermentation in malt wort, only after a period of six or eight days; during this time the mixture contracts a bad odor and an acid reaction. The conclusion from this fact is, that dough should be left to the action of the ferment only as long as is necessary to generate sufficient carbonic acid gas, to give the loaf its proper size. Greater difficulties are encountered with leaven than when yeast is used; for, as has already been mentioned, leaven is merely a portion of the dough in a state of fermentation, reserved for the next operation, to induce similar action in fresh portions of flour, to that which it undergoes itself, and which it effects in a manner similar to that of fermenting worts, with a fresh infusion of malt, as fermenting grape juice reacts upon a fresh extract of the fruit, or as yeast serves the same purpose; although, however, the action of yeast and leaven is analogous in this respect, yet the characteristics of the change are different, inasmuch as the fermentation produced by leaven possesses an acid character, arising from the slow and prolonged action at which the leaven is maintained, and which considerably favors the conversion of the alcohol into water and acetic acid.

During the action of the leaven, other compounds are probably formed, such as lactic acid and complex nitrogenous substances, arising from the decomposition of the plastic bodies of the flour; when the leaven is added in this stage of decomposition, it gives rise to like compounds in the dough, and the result is that such bread speedily turns rancid, and consequently is unfit for use.

Persons with weak digestive organs are unable to use bread made in this way—*black bread*—and the chief cause of its being so difficult of assimilation may be attributed to the source just described.

The fermentation of dough, as of all other bodies under similar circumstances, if allowed to proceed, ends in the putrefactive decomposition and the transformation of the organic principles into aeriform compounds. As already mentioned, when the ferment is undergoing the lactic and acetic stages, it communicates a similar decomposition in the dough; so it is with the putrefactive, for if the ferment has entered into this phase, it tends to induce the same change in the fresh paste, without any intermediate modifications of the fermentation being observed. A knowledge of the nature of the leaven, when mixed with the dough, becomes an important matter to the baker, whose interest it is to produce a good-looking and wholesome article. In no case should the acid change take place, before mixing the leaven with the flour and water necessary to make the loaf; as then, if it did not communicate perceptible acidity, the alcohol which assists to lighten the substance would be rendered inert; besides, it is always observed that such bread readily turns sour.

Yeast is easily retained in its first stage by admixture with sugar, but leaven demands more care. In Germany, where leaven is used to a large extent, the baker mixes a quantity of it with a portion of the flour and water intended for the next baking; as soon as the fermentation has raised this first addition, a larger portion of the flour is added, in the same way as before, the whole left again to ferment, and so on each time, till about one-half of the flour is in a state of fermentation. Such procedure is called by the Germans *Anfrischen*, and its object is to supply sugar for the maintenance of the vinous fermentation, and the exclusion of the acetous. By this process, the quantity of ferment or leaven required to raise a considerable portion of flour, is very small in comparison to what would be necessary if the whole of the flour was added at once; besides, the retention of the spirit and carbonic acid developed throughout the fermentation, tends to produce a loaf much more uniformly raised than it would be, if all the flour was submitted to the action of the leaven at the same time.

Various sorts of bread are obtained from the several kinds of flour. There is wheaten bread, or *firsts*, made of the finest flour; household bread, or *seconds*, which is somewhat coarser than the preceding; brown bread, or *thirds*, made from an admixture of two or more kinds of flour remaining after the firsts and seconds flour have been taken away; and *composition bread*, or what is made of the ground but undressed wheat. Much of the quality of bread depends on that of the grain, but even when the latter is of superior quality, the fineness of the bread is improved in proportion to the perfection of the dressing process.

BAKING APPARATUS.—Every baker should be most careful to provide a suitable and spacious room for the site of his operations. The ordinary apparatus and other requisite furniture for common purposes, are comprised in the following:—On one side of the room a large *dresser* should be erected, and over it a range of shelves. The *kneading-trough* occupies the opposite side of the room; it is generally from six to nine feet in length, three in height, about two and a half in breadth at the top, and tapering to the bottom, where it measures only about a foot and a half. A sliding or sluice-board is furnished in the interior, and a lid covers the whole. One end of the room is partly occupied by a copper boiler, holding from fifteen to thirty gallons of water, and the other end is appropriated to the oven.

The other utensils of the bakehouse are the *seasoning tun;* the *seasoning sieve,* made of hair, tinned sheet-iron pierced with holes, or perforated zinc; the *wire sieves* for sifting the flour; a *salt bin; yeast tub;* a *bucket;* a *spade* or *shovel;* a *bowl; scales and weights;* and a *large dough knife;* a *scraper,* used for cleaning the dough off the trough and moulding board; four or five short shovels of various sizes, attached to long handles, and called *peels,* used to put the loaves in, and also to take them from, the oven; *tin* or *iron plates; cloths* for covering the dough and bread; a *scuttle* or *swabber* for cleaning the oven preparatory to setting in a batch of bread; *supports,* of rectangular pieces of beech, fixed round the sides of the oven for the purpose of keeping the loaves in their places; the *rooker,* a tool in the form of the letter L, for the purpose of drawing out the ashes from the oven; a *hoe,* used for a similar purpose; and a *rasp* for detaching any burned parts from the baked loaf.

PROCESS OF BAKING.—When commencing to prepare the dough, the baker takes a proper quantity of water at a temperature varying from 70° to 100° Fahr., and adds the yeast, and afterwards a portion of the flour. The amount of water employed varies considerably with the quality of the flour, being from forty to sixty or seventy per cent. of the flour. According to URE, the following are the quantities taken, but as a standard the bakers use equal weights of water and flour:—

	Per cent. of water to form the dough.
French wheaten flour,	50·3
Hard Odessa wheat flour,	51·2
Soft Odessa wheat flour,	54·8
Do. do.	37·4
Do. do.	37·2
French baker's wheaten flour,	40·6
Flour of the Parisian hospitals, second quality,	37·8
Do. do. third quality,	37·8

Good flour always requires more water than inferior, to bring it to the ordinary consistence necessary for the retention of the volatile compounds which will be subsequently developed; the starch and gluten, in good flour, being in a more minute state of division, and therefore more retentive of water. Having mixed the water, yeast, and flour, as above, proportionably, to give the mixture a thick ropy consistence, the mass is permitted to rest for some time; a proper quantity of salt is next added, and the whole covered up in a small kneading trough in a warm situation. This mass is called the *sponge,* and the placing of it in a warm situation is termed *setting the sponge,* being in effect the inducement of the vinous fermentation in the sugar of the flour, signs of which appear in about an hour afterwards, by the mass becoming inflated from carbonic acid gas arising out of the decomposition of the sugar into alcohol. If the sponge be too thin, the bubbles of carbonic acid rise quickly to the surface, break, and are lost, leaving it almost in its original state; but when it is of moderate consistence, then the tenaciousness of the mass retards the evolution of the acid till it accumulates in large quantities, which distend the sponge until it can no longer retain it. The escape of the gas causes the dough to collapse; and as a further quantity of gas is produced by the progressing action of the ferment, the dough rises as before, till it acquires twice its original bulk, when it again falls. Were this operation of the sponge suffered to continue, it would last for a considerable time; but in that case, part of the valuable constituents of the flour would be unnecessarily destroyed, and the prolonged action would bring on the acetous fermentation, converting the alcohol into acetic acid, and spoiling the bread. After the first rising, if the baker judges that fermentation has pervaded the whole mass, he adds the remaining quantity of flour, water, and salt, and incorporates the whole material thoroughly by a laborious working, termed *kneading.* But if he thinks that the operation is partial, he delays adding the remaining part of the flour till the second rising. The kneading is continued till such time as the fermenting sponge becomes completely incorporated with the flour recently added; for without this precaution, the cellular texture of the loaf would not be attained, and the fresh flour would be left in doughy concretions in the mass. Hence the kneading forms a material part of the baker's work, and should always be well executed, as no loaf is properly made unless it has been thoroughly wrought up. By this mechanical operation, the glutinous parts of the flour are rendered so elastic, that the mass of dough which is made, is capable of expanding to twice or three times its volume without cracking. The criterion by which the baker judges when the dough is properly blended, is, by indenting it, and if it does not adhere to the hand on its withdrawal, the dough is properly worked.

Fig. 232.

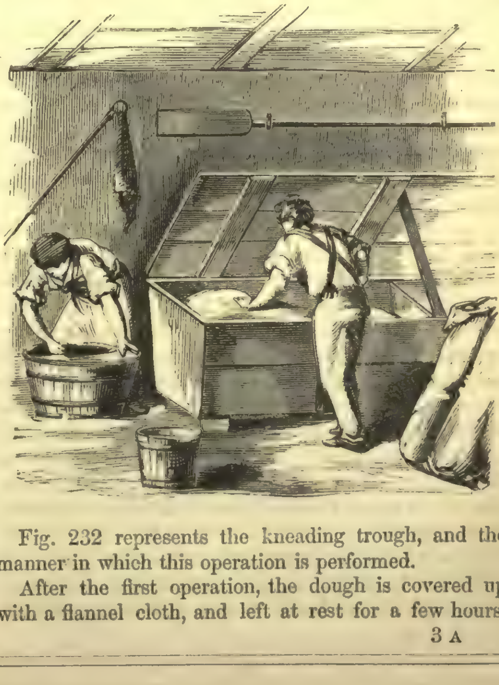


Fig. 232 represents the kneading trough, and the manner in which this operation is performed.

After the first operation, the dough is covered up with a flannel cloth, and left at rest for a few hours, during which time it is in active fermentation, and swells considerably. A second kneading is then given, not so much for the purpose of incorporating the whole of the fresh with the fermenting flour, as with the view of equalizing the carbonic acid formed in the mass, during the time the dough remained at rest, and preventing portions of the bread from being *sad;* it is, therefore, less laborious than the other kneading.

The dough prepared in this way is then weighed out into lumps of the requisite size; these are next shaped into loaves, or put into tins, as the case may be, and set aside in a warm situation till they have acquired about twice their bulk, partly from the generation of fresh carbonic acid, and partly from the expansion of that previously formed. The oven being prepared, the loaves, properly shaped and weighed, are introduced and allowed to remain till baked, after which they are drawn out with the peels, and now they stand no less than double their size before being introduced. It is absolutely necessary that the proper volume of carbonic acid should be generated in the dough before its admission into the oven, as the strong heat immediately arrests its further development, and the swelling of the loaf arises from the expansion of the bubbles already formed throughout the mass, which gives to it the light porous texture peculiar to good bread. Each of these cellular spaces is bound by a kind of integument, and they are so arranged that they form a succession of layers one above the other, and at right angles to the crust. When the loaf consists of an aggregation of the layers, it is called by the baker *piled bread.* Dr. COLQUHOUN contrasts the virtue of piled bread with the unpiled, by noting, that if the former be pressed in the hand it will crumble, and if thrown into hot water it will intumesce, disintegrate, and admit of being easily diffused; whereas, the unpiled bread, when treated similarly, yields a solid cohesive body, and hot water reacts upon it no further than to soften it into a permanently tough mass.

Many bakers of the present day use potatoes for assisting the operation of the yeast. About eight pounds of them, well washed and boiled in their natural coating, are thoroughly mashed in the seasoning tub, with two or three quarts of water, an equal amount of *patent yeast,* and about four pounds of flour; the mixture is then set aside, and covered closely with a flannel till it forms a ferment.

A sack of seconds flour may now be emptied into the kneading trough, and a fourth part separated, or *pinned up;* the ferment is then mixed with a sufficient quantity of water, cold in summer, but warm in winter or cold weather, and macerated so as not to leave any lumps; after which, the thick fluid is strained to separate the potato-skins, and added to the flour in the trough, where it is well mixed up by the hand, a little flour sprinkled over the mixture, and the whole left to rest for five or six hours. During this period, the sponge rises twice; the gas is allowed to escape the first time, but as the dough is at the point of breaking the second time, a quantity of water, sufficient to make up the batch, and in which the proper proportion of salt has been dissolved, is poured in, and incorporated. When this is effected, the *pin-board* is removed, and the remainder of the flour thoroughly kneaded with the sponge. It is then confined with the pin-board, and left for one or two hours, after which the remainder of the trough is sprinkled with flour to prevent the sponge sticking to the sides, and the whole mass is again kneaded; it is then cut into the proper sizes, weighed, moulded into suitable shapes, and introduced into the oven as before, taking the precaution, however, of preparing those first which had precedence in weighing.

The oven, previous to the moulding of the loaves, is thoroughly cleaned out with the swab, and the upsets or supports chalked, to prevent the loaves adhering to them. The various kinds of loaves are placed in the oven in connection as closely as possible; but the cottage loaves, rasps, *et cetera,* must be left some short distance apart, that they may be entirely crusted. Much manual skill is requisite in introducing the bread into the oven; when this is accomplished, the whole is retained in its place by a set-up placed in front, the door is next closed, and left so from an hour and a half to three hours, according to the size of the loaves, excepting that the door is occasionally opened to view the progress of the baking.

LATEST IMPROVEMENTS.—Having thus far treated of the panification, according to the usual system of ordinary bakehouses, the latest amendments will now be considered. The first of these, the use of the potatoes with the yeast, has been previously noticed. Instead of the eight pounds mentioned, however, many bakers add twelve pounds or more to two quarts of brewer's yeast, and this quantity is added to every sack of two hundred and forty pounds of flour.

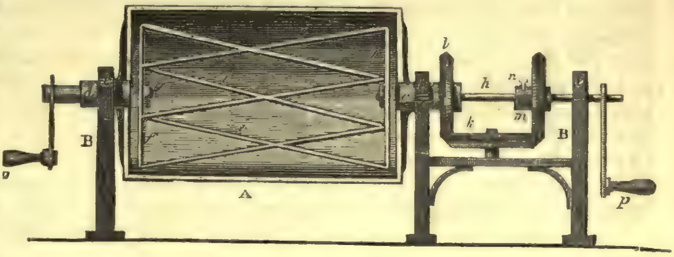
The yeast used by the bakers is obtained from the ale breweries. Porter yeast will not answer, as it communicates a disagreeable taste to the loaf. PEREIRA, who made several investigations to show the fungoid and vital construction of yeast, states that the bakers and brewers class it into several varieties, according to the quality of the beer from which it is obtained.

Ale yeast is the best and strongest, and is most extensively used in bread-making. Small-beer yeast is said to be weak, and rapid in its effects, and is sometimes used in making rolls. Yeast is of a fawn or light-brown color, and of a frothy consistence, when newly made it is in brisk action, and bubbles of gas escape from it.

German barm is an article much used by bakers and housekeepers. It is a paste-like substance, and is sometimes called *dried yeast,* and consists of sporules only, with but little adherent moisture and no gas. It is merely the yeast precipitated from a fermenting liquid, filtered off, and dried at a proper temperature. The following is the mode of preparing it:—Crushed rye is mashed with a certain quantity of barley malt, and the wort cooled to the proper temperature. Half a pound of carbonate of soda, and six ounces of sulphuric acid, diluted with their weight of water, are proportioned to every hundred pounds of the crushed grain employed, and mixed with the wort, and fermentation induced by the addition of yeast. From the strongly fermenting liquid the yeast is skimmed off, and strained through a hair sieve into cold water, into which it is allowed to settle. It is afterwards washed with one or two waters, and finally pressed in cloth bags till it has the consistence of dough. Its smell is pleasant and fruity, and it will keep in a cool place for two or three weeks. After this it passes into a putrefying decomposition, acquiring the odor of decaying cheese, and, like it, possesses the property of changing sugar into *lactic* acid, instead of into alcohol as before. A hundred pounds of crushed grain will yield six to eight pounds of the pressed yeast. It is made in large quantities at Rotterdam, and is imported to this country through Hull.—*Johnston.*

The utmost care is necessary to be observed in its preparation, as it is very readily spoiled; its vitality is destroyed even by slight mechanical injuries, by too high or too low a temperature, and also by chemical reagents. It is put up in Germany in hempen bags, each containing about half a hundredweight; when exported in casks, it has been known to burst them from evolution of carbonic acid. It should be carefully handled, as a slight concussion with another body injures it; even when packed, it is equally liable to be spoiled, as if the bag, in being removed, falls, so as to receive a shock, it is *killed*, and scarcely any of its valuable properties as a ferment remain. HASSALL states that yeast which has been thus injured may easily be distinguished from the good, unaltered article, by its color becoming darker, somewhat like the change which an apple or pear undergoes when it putrefies, and, from being crumbly, it becomes soft and glutinous, adhering to the fingers like flour-paste, sometimes emitting a fetid, disagreeable odor.

Fig. 233.



The injured and uninjured substances submitted to a microscopic examination, exhibited no difference in their appearance.

The patent yeast before alluded to, is an infusion of malt and hops, the latter being intended to diminish the propensity of the solution to acidify. It is a thin aqueous liquid, through which numerous sporules of the yeast plant are disseminated. Many bakers add either common yeast or German barm, with an infusion of flour or potatoes, in preparing the patent yeast, their object being to make the product more effectual, as these substances supply, in greater abundance, the nourishment of the yeast cells; they likewise contain more material for the generation of carbonic acid.

Another improvement in bread-making which has been effected of late, is in the kneading of the dough. In extensive bakeries, the trouble of mixing the flour, yeast, and other ingredients, is so great that manual labor could not accomplish it; hence machines have been constructed to serve the same purpose.

The best and most ingenious of such contrivances is that patented by Mr. CLAYTON. It consists of a rotatory drum, or barrel, mounted on gearing, with a hollow axle, and an interior frame of cast-iron made to revolve by a solid axle, which passes through the hollow one. The revolving drum and frame are made to turn in contrary directions, that time and labor may be economised: besides, this change causes the machine to act similarly to the hands of the baker; for by it the dough is inverted at each time the wheel is changed, and the knives, or diagonal cutters, which are fixed in the frame, tear the mass asunder, and again reunite it in every different form, till the entire ingredients are completely incorporated.

Fig. 233 is an elevated section of the apparatus embodying these improvements. A is the barrel or drum into which the several ingredients for the formation of the dough are put; it is mounted on the framework, B B; *c d* are the hollow axles which turn on suitable bearings at *e e; f f* is the revolving frame which is placed in the interior of the barrel, A, and mounted on the solid axles, *g h*. The ends of the interior revolving frame are braced together by the parallel slanting spars, *i i i*, which act with great effect in blending the dough, as the case is put in motion. Either the barrel may be made to revolve without the frame, or the frame can be put in motion, leaving the barrel stationary; or, if necessary, action can be communicated to both. The gear work and winches, at each end of the machine, are the means by which the operation is performed. When it is requisite to put the barrel and interior cylinder in motion in opposite directions, the hollow cylinder of the wheel, *m*, is screwed tightly to the axle, *h*, of the interior revolving machine, by the screw, *n*, and by turning the winch, *o*, it will be found that both these motions will be given to the machine.

The interior cylinder, *f f*, may be worked by unscrewing *n*, and turning the winch as before; for the axle, *h*, does not communicate with the wheel, *m*, except by the screw, *n*. Again, if the rotatory action of the barrel be wanted, leaving the other stationary, it may be obtained by turning the handle, *p*, which, however, gives motion to the wheels at the opposite end, but this has no power to act upon the inner cylinder, if the screw, *n*, be disconnected.

Another kneading machine used in some of the bakehouses of France is represented in Figs. 234 and 235, the first being a longitudinal section, the line of division passing through the axis, and the other a front elevation. P P, the frame of the machine, is made of wood, and divided into three compartments for the reception of the dough. The wooden bars, *o o o*, are placed in the interior of the chambers, so as to divide the dough whenever the cylinder revolves. One portion, D, may be opened and laid over upon the other by means of a hinge and movable joint when the dough and flour are introduced. Of A, B, and C, the three divisions of the machine, two—B and C—are reserved for making the dough, the other being used in preparing the sponge. *a* is a pulley which receives its motion from the engine, and transmits it to the cylinder by the pinion, *b*, and the spur-wheel, *c*; *d* is the fly-wheel to regulate the motion of the machinery; *g* is a break to act upon the fly, *d*, by means of a lever, *h*; and *i*, the pillar of the fly-wheel.

Fig. 234.

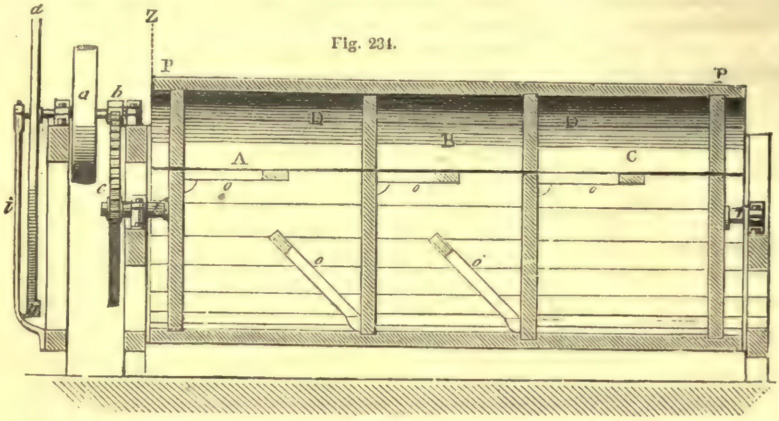
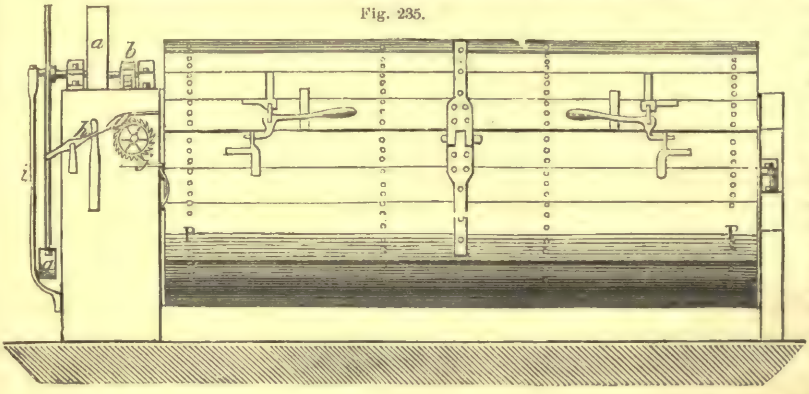


Fig. 235.



The machine is furnished with a wheel to indicate the number of revolutions it makes, which, however, is not seen in the drawing. The compartments of the machine are furnished at pleasure with cross-bars, which serve to draw out the dough. When operations are continuous, the sponge is always being prepared from a mixture of—

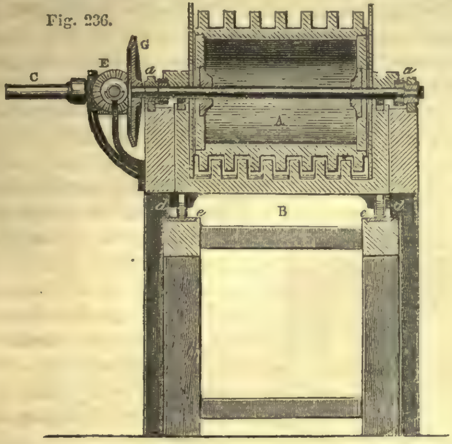
275	pounds of ordinary leaven,
148	pounds of flour, and
76	pounds of water, making a total of
499	pounds.

The person in charge of the mechanical kneader shuts down the lid, and puts it into operation. At the end of seven minutes a bell sounds, which announces that the number of revolutions is performed, and summons the attendant to examine the dough; the cylinder is forthwith opened, and after verifying the right state of the leaven—adding water if it be too stiff, or flour if the reverse be the case—the lid is once more closed, and the machine again put in motion. In ten minutes afterwards, the bell sounds a second time, which tells that the kneading is completed. As much sponge is obtained from the two kneading compartments, containing each about five hundred pounds of dough, as keeps two ovens always at work alternately.

For this purpose, one hundred and sixty-five pounds of the dough are taken out of each of the compartments, B and C, making in the whole three hundred and thirty pounds; to this quantity about two hundred pounds of flour, and one hundred pounds of water—about ten gallons—are added; the united weight of which is about six hundred and thirty pounds. The two compartments are again replenished with the original quantities of flour and water, to make up the mixture, as before stated; namely, one hundred pounds of flour, and about fifty of water, and the cylinder set working as before.

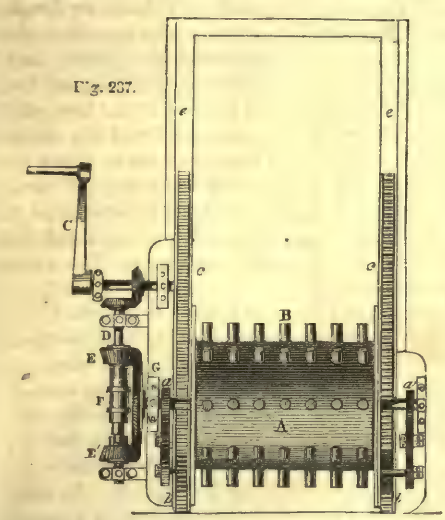
The same means which work the leaven in the compartment, A, suffice to make the paste or dough in the division, B. On opening the cover, any portions adhering to the sides or cross bars are scraped off, and the whole removed, after which a similar quantity of flour and water is introduced to prepare a second batch for the next oven. The water is generally raised to a temperature of from 77° to 86° Fahr. in cold weather, and about 68° in summer. This is attained by mixing cold water with a due proportion of water from a basin placed over the oven, and which is at 160° Fahr. or thereabouts. At each addition of water, from half to three-quarters of a pound of fresh dried yeast is distributed through it. While this fresh quantity is kneading, the paste already produced is turned out upon the table, to give it its round or oblong form, and there is pressed upon with the fore-arm or roller, giving it the cavity which characterizes the form of cleft loaves. All the lots of dough of the size of one kilogramme—two pounds and a quarter nearly—called cleft loaves, are placed upon a cloth stretched over a board, a fold of which is raised between every two loaves. The cloth thus laden with from ten to fifteen loaves, is transferred to the wooden shelves in front of the oven. While under the influence of the moderate temperature in this antechamber, or *fournil*, the loaves rise well and easily, and after they have attained the proper size they are transferred to the oven, an operation termed *enfournement;* it is performed by putting each loaf on a wooden shovel dusted with coarse flour, and placing it thereby on the sole of the oven, all being closely packed, but yet disconnected. A long gas-burner introduced into the oven offers great facilities to the workmen, as the light enables them to view every part of the oven, and arrange the loaves in their proper position.

Fig. 236.



Subjoined is a brief sketch of the apparatus of M. DISDIER, of Marseilles, which is said to be very applicable to the purposes of the extensive bakery. It is distinguished by the addition of a kind of railway, on which the machine is moved with facility from one point to another.

Fig. 237.



Figs. 236 and 237, representing a vertical section and plan of this apparatus, convey an exact idea of its construction.

It consists, as will be seen, of a cylindrical drum, A, armed with teeth or projecting pins over its whole circumference, and a longitudinal trough, B, furnished with similar projections, between which those of A pass.

Rotation is communicated to the drum by means of a winch, C, the axis of which communicates by a pair of bevil-wheels with a longitudinal shaft, D, which carries also two conical pinions, E E′, and a muff, F, to bring them into gear successively with the wheel, G, and thereby to turn the drum alternately to the right and left.

Pinions, *a*, fixed to the axis on each side of the drum, transmit, while rotating, the movement to two other pinions, *b*, which gear with the long racks, *c*, so as to drive the latter, and communicate motion at the same time to the moveable trough, B. This trough is furnished, for that purpose, with rollers, *d*—Fig. 236—which run on the two fixed and parallel bars, *e*, forming, in fact, a railway.

Such an arrangement bears a great resemblance to the machine for kneading the paste which is used in the manufacture of ship-biscuits.

THE OVEN.—Until of late, very little improvement has been effected in ovens, and those in use at present in many provincial towns resemble, even in minute details, that discovered in the excavations of Pompeii.

Figs. 238 and 239 are a ground plan and an elevated section of the ordinary oven in general use in most countries. The space, A, wherein the bread is baked, is of an oval shape, and the usual dimensions are twelve feet by ten. The bed may be made of clay, but fire-bricks or tiles are better, and in this country it is mostly constructed of such material. In many parts of the Continent, the beds of the ovens are formed of hewn *tuff* stone. The arch which covers the bed is low, being at most only about one foot and a half in height, and the entrance door, B, is from one and a half to two and a half feet broad; through this opening, both the fuel which heats the oven, and the bread to be baked, are introduced. At the back of the oven, three flues, *a a a*, are situated, and these come in a horizontal direction to the front of the oven, where they unite before entering the chimney, D. The vapors and smoke from the burning coals, wood, or other fuel, are carried off through these flues, the draught of which is partly shut off by means of the damper, *b*. C is the space where the charcoal which is made in the oven is kept, and the pit, *c*, is provided to bring the workman on a convenient level with the door, to enable him to deposit the bread in the oven. E is the bakehouse, which is retained at the proper temperature for raising the dough by the superabundant heat from the oven and flues. In front of the oven a boiler is situated, for the purpose of heating the water used in making the dough. The fuel in the oven is kindled by introducing a piece of lighted firewood through a small aperture in the door. As the draught of the oven is never very strong, the fuel often employed to heat it is thin boards, or brushwood, which readily ignites, as by the use of large logs the oven would not be heated properly. All

Fig. 238.

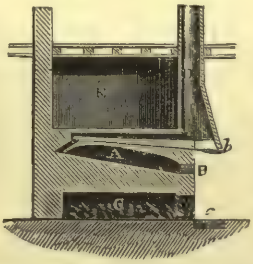
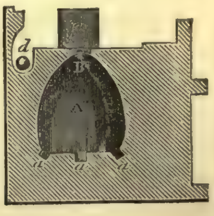


Fig. 239.



the heat is derived from the flame which proceeds from the wood; as soon as the charcoal begins to glow it is abstracted, and the bed of the oven prepared for the reception of the bread. In many ovens which are not of large dimensions, and which are fed with very thin wood, the anterior flues are not supplied, but two small apertures rising in the arch at the front answer the purpose, and sufficient air enters by the door. Much heat is lost in this mode, but the loss is partly covered by the charcoal produced. In many villages turf is used, and is found to answer better than wood.

It is well known that the back part of the oven is warmer than the front, and to insure an even temperature the glowing coals are detained for some time near the door of the oven, to raise this part to a higher degree of heat. An hour's heating is always sufficient to bring the oven to a proper temperature, and sometimes half an hour will serve the purpose; the quantity of fuel also decreases from the first, till the materials attain a regular temperature, and then becomes constant. The fuel being consumed and the charcoal withdrawn, the bottom of the oven is then thoroughly cleansed out with a brush and moist cloth or swab. The heat of the oven is next proved by casting in a small portion of flour; as long as this assumes only a brownish color, the proper degree is said to be attained, but if it should be charred, the introduction of the bread is delayed till the proper temperature is reached. The workman now introduces the bread, by placing two or three of the prepared loaves which had been hitherto left to rise, and are found considerably enlarged, each time upon the peel, the latter being slightly dusted over with a little bran, or refuse flour, to prevent the adherence of the dough; a lamp or gas light being placed beside the door and within the oven to illuminate the hearth, so that he can conveniently arrange each loaf in its proper position. When the whole of the batch has been introduced, the door is closed, and made air-tight by a little cement or plaster. In the course of from twenty minutes to half an hour the batch is examined, and, if requisite, some of the loaves from the further end are changed to the front and colder part of the oven, those from the front being put to the back, after which the door is again closed and sealed till the bread is baked. The time required in this operation is dependent upon the construction of the oven, as also upon the size of the loaves; but it generally extends from one and a half, to two or two and a half hours. Heat is derived during the baking from the hearth and elliptical arch of the oven; the former yields it by contact, and the latter by radiation. When the baked bread is withdrawn, the oven still remains very hot, but is incapable of baking another batch; it must, therefore, be heated with a further portion of fuel, to bring it to the proper temperature; the quantity required, however, is considerably less than what was used in the first instance, and it continues to diminish till all the parts of the oven and those connected with it have acquired a uniform heat, after which no more fuel is consumed for baking each batch, than one-third of the quantity requisite in the first instance to bring the oven to the proper temperature.

Evidently, the use of such ovens as those described are insufficient where an extensive business is carried on; besides, a much greater expenditure is incurred from the amount of fuel required at each operation. Of late years, ovens which are continuous, have been constructed, the advantages of which have been thoroughly established on account of the economy attending their use, as well as for the regularity of their baking. In Germany, one of considerable repute is erected at the military bakehouse in Hanover. This oven is heated continuously by two furnaces; the bed of the oven is supported by numerous pillars erected upon the foundation, and the flues which recede beneath it from the fire, and return along the arch at the top to the chimney; portions of the flame pass off laterally, and meet over the head, that the heat applied at the neck of the oven may be equalized with the hinder part. This oven is capable of baking, at each operation, three hundred loaves of seven pounds each, or two thousand one hundred pounds of bread; the fuel consumed being only 6·4 cubic feet of coal: four such bakings can be made in a day, and the average quantity of fuel required is only sixteen cubic feet; hence the cost for fuel is only about one-third of a penny for every hundred pounds of bread, whereas, in the usual methods followed, the bakers of Darmstadt calculate the cost of fuel for baking the same quantity, to be from four to four and one-third pence.—*Knapp.*

In Paris, famed for the beauty and quality of its bread, the model bakehouse of MOUCHOT is upon a similar principle, and will be described. The kneading cylinders used at this establishment have been already referred to, and now the general arrangement and its other appendages will be considered.

Fig. 240.

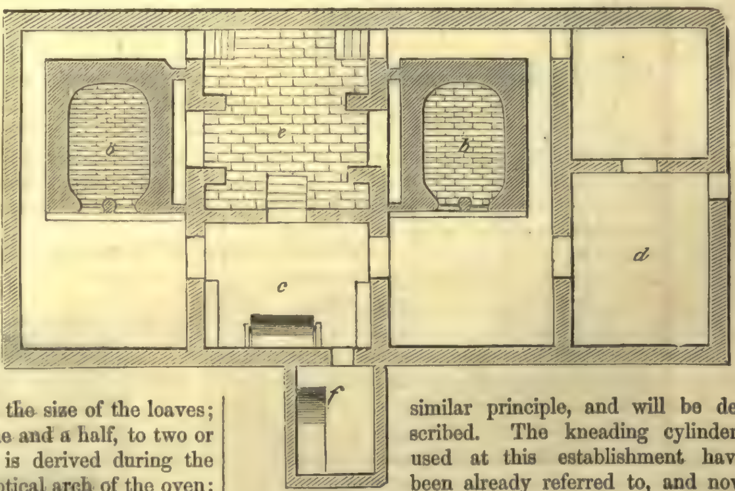


Fig. 240 is a ground plan of the bakehouse, the upper part of the building being appropriately laid out into a granary, whence the flour is let down to the bakery as required. In this figure, *b b* are the baking ovens; *c* is the kneading apparatus; *d*, the space allotted to machinery for raising the bread into a store-room in the upper part of the building; *e*, a space common to the two ovens, and in which the hot air is retained to keep them at the due heat before it enters the chimney; *f*, the wheel which gives motion to the machinery for making the dough.

Figs. 241 and 242 are elevated sections of the preceding on the line, X X.

Fig. 241

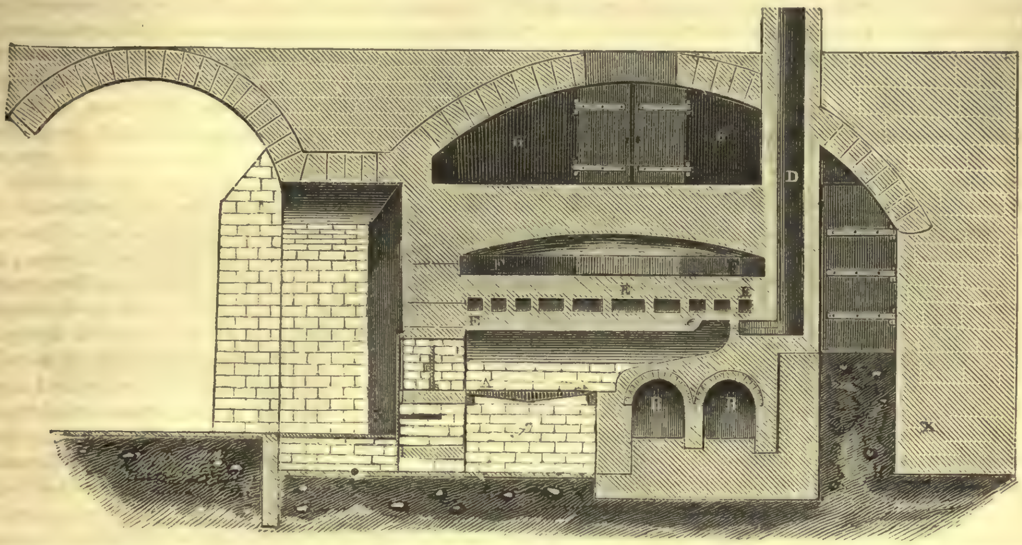
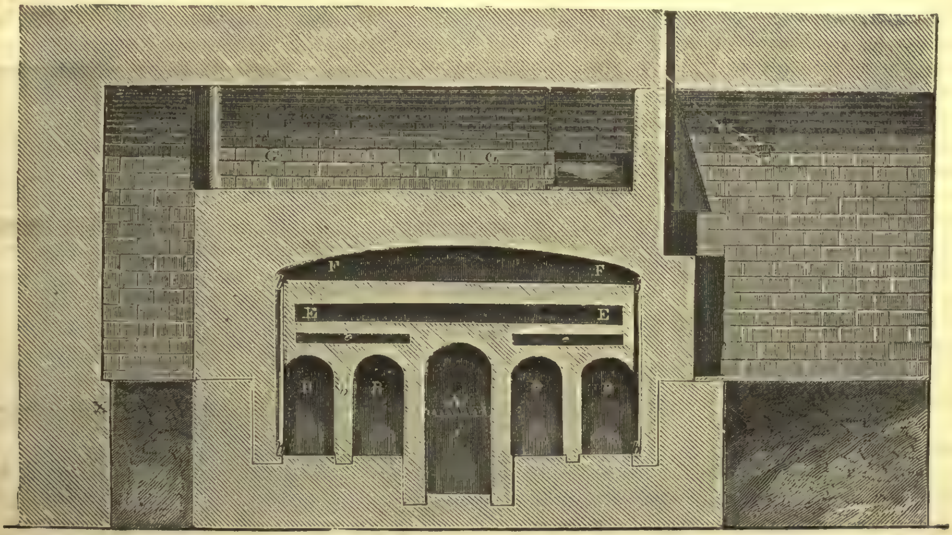


Fig. 242.



The oven is called *four aérotherme* by the French. The corresponding parts are indicated in the preceding figures by the same letters. A is the fire-grate whereon the fuel, which may be pit coal or coke, is consumed, and *j* the ash-pit; this fire is surmounted by an arch, and the flame and heated vapor ascend by two spaces, *e*—Fig. 242—and pass under the hearth or bed of the oven, F F, in the channels, E E. B B are chambers at each side of the grate, wherein the air is heated without coming in contact with the fire. From these reservoirs the warm air enters the oven by two apertures, one of which opens directly into it, while the other communicates with the flues, that the air may be more highly heated by coming in contact with the products of the combustion, and which are carried off through those spaces. The sole or bed of the oven is at first heated with dry wood, as the ordinary ovens, and when once the proper temperature is attained, it is kept up by the warm air which is admitted into the oven in the manner described, and by the hot air which always flows along the flues, E E, beneath it. During the baking, the air which enters the oven gets saturated with moisture, and in this state passes off at the top, by an opening which connects it with the reservoir, B, and returns immediately to serve the purpose already effected repeatedly, as long as the oven is at work. D is the chimney which carries off the smoke and excess of vapor when the oven has been heated, and G G is an enclosed space for retaining the warmth, and which is used to heat the lumps of dough, preparatory to their being introduced into the oven.

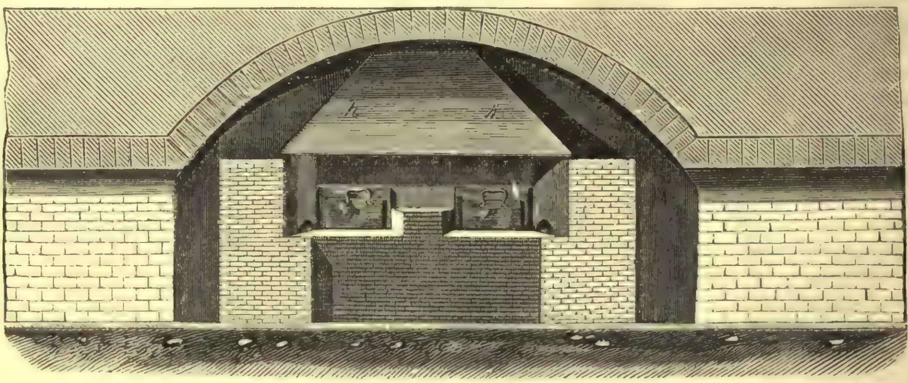
Fig. 243 is a front view of the oven, showing the doors at *p p*.

DUMAS describes the process of baking with this oven as follows:—All the portions of dough, of the size of the one kilogramme loaves, called *pains fendus*, or cleft loaves, are placed on a cloth, of which one fold is brought up between every two loaves, the cloth being first stretched on a board. Thus loaded with ten or fifteen loaves, it is carried on wooden bars or bearers, and placed in front of the oven.

All these dough loaves rise easily by the effects of the mild temperature of the bakehouse. When the dough is sufficiently raised, the next process is the *ovening*.

This operation is performed by placing each loaf successively on a wooden shovel, lightly powdered with *fleurage*—flour mixed with a little fine bran.

Fig. 243.



The loaves are disposed on the oven floor, as near as possible to one another, without touching. This operation is rendered easy by the new mode of lighting with gas.

The gas is brought by underground pipes to a tube placed near each of the doors of the oven. This tube has several joints, which allow the introduction of the burner into the interior, and it can be easily moved to all parts of the sole of the oven in succession. The inspection, and the charging and clearing, are, therefore, performed with the greatest facility.

When the oven is charged, the gas is drawn out, and the two doors shut; the two registers are thrust in to avoid firing the dough too much. But as soon as the temperature is brought down 18° Fahr.—*id est*, from 572° to 554° Fahr.—the registers are opened, to bring up the temperature to what it was at first, by permitting the circulation of warm air, which comes into the interior of the oven from the cavities below, situated round the furnace.

The baking being completed, the light is again moved into the oven, and the clearing or discharging proceeded with.

If the temperature has been sustained at about 572° Fahr., which is easily managed by inspecting the exterior tube of a thermometer fixed with its bulb in the interior, the 300 kilogrammes of dough, divided into 1 kilogramme loaves, will be fired in twenty-seven minutes. The charging of the oven having occupied ten minutes, and the clearing about the same period, each baking, therefore, requires, in the whole, a period of forty-seven minutes.

Now, if allowance be made for some accidental delays, or the longer time required for loaves of a larger size, it may be taken for granted that a total duration of one hour is sufficient for the firing of each ovenful, or batch, consisting of 260 loaves of one kilogramme each, or 6,240 kilogrammes in every twenty-four hours. The temperature in the interior of the oven, is often far greater than is requisite, particularly in the small ovens; hence the bread often has a burnt deep crust, which is disagreeable to the taste. If the temperature at the introduction of the dough be too high, a burnt crust is almost immediately formed, while the heart of the mass is little else than raw dough, and it frequently remains so during the usual time the bread is left in. The reason of this is, that the carbonaceous covering of the loaf is a bad conductor of caloric; and, therefore, the heat is prevented penetrating the mass. On the contrary, when the temperature is moderate, the heat is transmitted to the interior of the loaf before the exterior becomes carbonized. It is absolutely necessary that the heart of each loaf should be maintained at a temperature of 212°, to render the starch soluble. The starch, gluten, albumen, and other parts of the flour, are more intimately blended by this application; and the water which hydrates them, is retained in the solid parts. The excess of water is evolved, and the carbonic acid and spirit are expanded, so as to cause the increase of the loaf, and confer the piled texture which causes the bread to be so much esteemed. DUMAS attributes the great difference which is to be observed in bread to the irregularity in the temperature, especially when such bread is baked in the ordinary ovens, heated by fuel strewed upon the bed: firstly, because the temperature of such ovens, from the manner in which they are heated, can never be uniformly diffused; and secondly, because the oven cannot preserve the uniformity of temperature which is so desirable; for, supposing that the heat is equally distributed at the time of abstracting the fire, the exterior parts are considerably cooled during the time the bread is being introduced, and it is precisely in this part that the loaves remain for the shortest time; hence, unless there is a transposition of these into the place occupied by those more highly heated, it is evident that either the latter will suffer from the effects of high temperature, or the bread in front will be only imperfectly baked.

If the heart of the loaf has not attained a temperature of 212° during a period sufficiently continued to effect the dissolution of the starch corpuscles, and blend them with the other valuable constituents of the flour, the bread will be heavy, dense, and doughy, difficult to digest, and loaded with extraneous moisture; qualities highly prejudicial. Bread may be baked at a temperature not exceeding 212°; but then, that most necessary part, the crust, is wanting; besides, the piled structure is not so perfect as when baked in ovens raised to a higher degree. As regards the solution of the starch and its intimate incorporation with the albumen and gluten, *et cetera*, it is perfectly the same as when the dough has been submitted to a higher heat; for in the latter case, the heat acquired by the central parts of the loaf is not greater than 212°, a fact easily demonstrated by cutting a loaf open, and burying the bulb of a thermometer in the dough; the mercury will not rise higher than 212°.

In the better sort of ovens—as those of MOUCHOT—the internal temperature is registered by means of a thermometer, and whenever the heat rises higher than 554° to 572° Fahr., the dampers which shut off the draught of warm air are inserted, and after the interior has cooled to about 280° Fahr., they are adjusted to keep this up, and thus an equality of temperature is gained. The lowest heat at which the bread can be efficiently baked is from 320° to 400° Fahr.; that of the *four aérotherme* far exceeds this, but the species of bread baked is different. Were large loaves of eight to ten pounds weight introduced into these ovens at their usual temperature, for reasons before assigned, the result would be unsatisfactory.

From what has been said, it is evident that overheated steam could not be conveniently employed for heating ovens, as a pressure of from four to fifteen atmospheres would be requisite.

The yield of bread is generally about ninety quartern loaves per sack of two hundred and eighty pounds of flour. If the flour, however, be of the best quality, more water is retained, and a greater weight of bread results. When the dough is made of the proper consistency, the usual loss by baking amounts to about one-tenth of the weight of the mass of dough, or one ounce and a half to the pound.

As the gluten of the flour plays an important part in the fabrication, both as a nutritive agent and as a means of increasing the yield of bread, it is highly necessary that every baker should be made acquainted with this fact, so as to enable him to bake both for his own and the public good. To give him an insight into this part of the subject, it may be well to quote from DUMAS. He says:—The most direct method to estimate the quality of flours, would consist in submitting them to that regular, and, in some sort, mechanical purification which has now been arrived at, and which is sufficiently constant to render easy a comparison between the results obtained from different original materials. One might thus judge of their yield, and the quality of the bread produced; but it may be conceived also, that several bakings or batches must be tried for this purpose, as well to diminish the influence of the leavenings as to obtain a mean sufficiently accurate.

Perhaps results equally certain would be arrived at, more promptly, and with smaller quantities, by taking pretty equal portions of water and flour, kneading them at the same time, and at a like temperature, in a small mechanical kneader; determining the *rising* of the dough by equal quantities of bicarbonate of soda dissolved in water, and decomposed at the moment of putting the material into the oven, by adding a definite portion of alum rapidly mixed into the dough; finally, submitting the latter to the baking process in a small oven at the constant temperature of an oil-bath.

The Editor is of opinion that if this method were constantly adopted, it would not only be found exceedingly troublesome, but extremely uncertain; further, it would not fulfil the desideratum, the object being, not merely to ascertain the *yield* of the flour, but also the *quality* of the bread produced therefrom.

If the former were always in proportion to the latter, this process might, perhaps, to a certain extent, become available, but it has been fully proved that such is not the case; or, at least, that with flour of an inferior quality, the baker usually manages to obtain a quantity of bread *equal in weight* to the article which superior varieties of flour would produce.

It would, therefore, be much better and safer to analyse the flour, and estimate the per centage of foreign organic or inorganic ingredients which might have been mixed with it.

The following results of experiments on some samples of flour by DUMAS' mode are given, however, by way of example:—

Names of the corns.	Weight of flour employed.	Equivalent. Dry.	Gluten. Moist.	Gluten. Dry.
Tangarock,.........	100	87·36	45·0	22·67
Odessa,.............	100	86·90	33·33	15·0
Saissette,...........	100	84·92	30·0	12·66
Rochelle,......... .	100	87·15	27·33	11·17
Brie,..............	100	86·55	26·0	10 66
Tuzelle,...........	100	87·01	22·6	8·3

All these flours, converted into bread under the same circumstances, gave returns pretty approximate to each other. A conclusion may be drawn from the products of the two very different flours in the list—the first and the last but one in the preceding table—as regards the proportion of gluten. The flour of Tangarock wheat, gave 1·430 of bread, weighed two hours after the baking; whilst the Brie flour gave 1·415; but the bread of the former, in which the gluten had very little increased the return, contained in nearly the same proportion a greater quantity of water, as will be seen from the following table, in which is included the results obtained with other samples of bread :—

Name of Bread	Weight of the loaves tested.	Time elapsed from taken out of the oven.	Equivalent in dry substance.	Proportion of water.
	kil lb.	Hours.		
Munition bread,	1·5 = 3·3	2	48·50	51·50
Do. do.	1·5 = 3·3	6	48·93	51·07
Do. do.	1·5 = 3·3	10	48·89	51·11
Do. do.	1·5 = 3·3	18	49·14	50·86
Mean,	1·5 = 3·3	9	48·86	51·14
Household bread with flour of Tangarock wheat,	3·0 = 6·6	12	52·02	47·08
Do. do. Brie do.	3·0 = 6·6	12	52·56	47·44
Mean,	3·0 = 6.6	12	52·29	47·26
Ordinary white bread of Paris,	2·0 = 4·4	12	54·50	45·42
Do. do.	2·0 = 4·4	6	55·10	44·90
Do. do. baked in hot oven,	1·0 = 2·2	2	54·01	45·69
Do. do. do.	1·0 = 2·2	4½	55·65	45·33
Do. do. do.	1·0 = 2·2	10	55·97	43·03
Do. do. do.	1·0 = 2·2	24	56·55	43·45
Mean,	1·3 = 2·9	9·75	55·30	44·63
Dough of munition bread,	— —	—	49·10	50·90
Do. hot-air oven bread,	— —	—	54·64	45·40
Flour of munition bread,	— —	—	84·10	15·90
Do. hot-air oven bread,	— —	—	83·45	16·55

This table shows that the quantity of water added to the flour in the kneading of the dough for ammunition bread, should be an average of one hundred and five per cent.—saving a small quantity evaporated before the ovening; and consequently, one hundred of dry meal would represent two hundred and five of dough. This large proportion of water renders the working of the dough much easier, but it retards the baking, increases the thickness of the crust, and leaves the soft bread more impregnated with moisture, and in some degree pasty, as it contains an average of 0·5114 of water.

In the ordinary white loaves of Paris, and those of the colleges, baked in the hot-air stove, the proportion of water added to prepare the paste required to be 52·27 per cent., and the flour perfectly dried represented, for 100 parts employed, 181 of dough obtained.

Comparing the preceding numbers, it will be observed, that for an equal weight of the soft part of ammunition bread, the real substance is found in least proportion in the bread furnished to the colleges of Paris, and that the difference rises to fourteen per cent.

The yield of the ordinary white flour at Paris, is from one hundred and two to one hundred and six loaves of two kilogrammes each per sack, weighing one hundred and fifty-nine kilogrammes; from these data the following table may be deduced :—

Weight of sack of flour.	Number of loaves.	Weight of bread.	Increase, the weight of ordinary flour being one.	Proportion of the weight of dry flour to weight of bread.
kilogrammes.		kilogrammes.		
159	102	204	1·283	:: 1:1·60
159	104	208	1·30	
159	106	212	1·333	

Thus it is seen that the mean yield of the flour corresponds to one hundred and thirty parts of bread for one hundred of flour employed; or, admitting that the latter contained 0·17 of water, the produce would be equivalent to one hundred and fifty of bread obtained for one hundred of real flour, or flour deprived of water.

It would further result, that this bread, containing in the whole 0·53 of dry substance, and 0·44 of the soft part, the proportion of the weight of the crust to the soft bread would be from 25 to 75 in the long loaves subjected to experiment.

On reviewing what has been already said upon the nutritive parts of the cereals and upon bread, it will be seen how much more adapted wheat flour is to the preparation of white or bakers' bread, than that of the other cereals, a circumstance dependent upon the nature and quantity of its glutinous substances, which are only present in small proportions in the latter. When flour from barley, oats, or rye, is made into a dough and fermented, the carbonic acid is not retained as in the dough from wheat flour, owing to the want of tenacity which the latter acquires from the hydration of its gluten; hence, when a dough made of any other flour than wheat is fermented and baked in the usual way, the bread produced, besides being inferior in color, is dense and only very imperfectly piled. Machines in the preparation of such dough are inferior to the manual process, in intimately bringing the hydrates of the different compounds into close proximity, and also in diffusing the action of the ferment; for, in the former case, though much saving results, the dough is liable to be mixed with extraneous substances, such as grains of corn or other matters which may be inadvertently dropped into the flour; and likewise the flour may, by the rolling of the bars, be thrown into small lumps, which, when coated exteriorly with moisture, would pass through even a prolonged action before they become disintegrated: whereas, in the manual kneading, such can scarcely ever escape the notice of experienced workmen.

When kneading with the hand, great facility of proper fermentation is allowed to the dough; in the mechanical process, the only time permitted for the generation of the carbonic acid is after the formation of the loaves; provision is, however, partly made by preparing the dough or sponge beforehand, but whatever carbonic acid may be formed in this way, is nearly expelled in the subsequent kneading.

At first sight, a marked difference is noted between the exterior part of a well-baked loaf and its interior; the former is of a light-brown color, hard and thick; while the latter is soft, white, elastic, and interspersed with numerous cells: these differences are brought about by the chemical action of the heat applied in the oven, and which has never been fully ascertained.

Reichenbach attributes the brown color of the crust to the presence of a peculiar body which he calls *assamar*. Heat acting upon all organic matters, however indifferent, transposes their elements into other compounds; and when the carbonaceous matter is in excess, it happens that carbon is more or less isolated from its original state in the heated body. It may be thus with the bread when heated, the fluid matter in the starch granules bursts the integument of the grain; by a further increase of temperature it is converted into gum, and the next transition, from the continued action of the heat, might be the carbonization of those parts, or their conversion to the assamar above referred to.

With the exception of the coagulation of the albumen in the gluten, and the transition of the starch from the insoluble to the soluble or pasty state, no important change takes place besides what has been already mentioned.

Starch can be readily detected in any part of the loaf, by moistening it with a solution of iodine; a blue color quickly makes its appearance. By macerating bread with water, and acting upon the extract with a little diastase or malt extract, the starch, which was at first easily detected, can in a short time be no longer noticed by the most delicate tests.

The crumb is regarded by **Knapp** as merely an intimate mixture of starch paste with gluten, the separation of which may be effected by washing with water in the usual way for removing the starch from the crude gluten.

UNFERMENTED BREAD.—Two varieties of this bread are to be met with among different classes. One consists of merely flour and water, with a little salt as a seasoning. Wheaten bread when so used is always made into biscuits; and when rye, oat, or barley flour is used in this manner, cakes are formed, as the want of gluten in these excludes them from being constructed like the ordinary bakers' loaf; they are often substituted for wheaten flour in biscuit factories, but mixed with a better ingredient, as their dough is not so elastic as to be extended in the thin shreds used in this manufacture.

The other variety of unfermented bread is usually made of wheat flour, in loaves the same as those already detailed. This kind is prepared by intermixing either volatile bodies, or substances which disengage carbonic acid. As the raising of a loaf is merely a mechanical action of the carbonic acid and spirit, it occurred to some medical men and chemists, that if this body could be supplied without instituting a fermentation in the bread, the whole of the sugar might be retained, and the bread would be more nutritive, while others, who had misgivings as to whether the fermentation of the dough did not tend to produce injurious effects upon the consumers, hailed the idea with enthusiasm; in fact, several patents were immediately obtained for this purpose. Various means were resorted to, such as kneading the flour with water saturated with carbonic acid, mixing bicarbonate of ammonia with the flour, *et cetera;* Dr. **Whiting** sealed a patent in 1837 for incorporating an alkaline carbonate with the flour, and kneading this mixture with water acidified with hydrochloric acid, in the exact proportion to convert the soda employed into chloride of sodium, while carbonic acid was disengaged to distend the dough.

Dr. **Thomson**, who also took up the subject, stated the increase of bread from a sack of flour to be considerably larger than if the flour was submitted, as usual, to the action of leaven or yeast. This increase was said to be seven loaves in the sack, others asserted that it amounted to ten per cent.; but the latter is decidedly an error, for, by careful experiments on a large scale, it was found not to exceed two per cent., and was not often so high as this—the proportion of water used to prepare the dough being the same as when making the fermented bread. Butter or other oleaginous matters, as also bicarbonate of soda and tartaric acid, are likewise bodies resorted to for raising the dough; the former is used by confectioners for making pastry, and the latter, like the preceding compound of soda and hydrochloric acid, for making loaves. When butter is the agent, it is mixed with the dough, which is then rolled out into a thin sheet, and recoated with a thin layer of butter; after which the operator folds the sheet of dough outwardly from him; he next rolls it out as before, and lays on a second coating of butter, and proceeds as in the first instance, till the mass has been rolled and buttered eight or ten times. Some only butter the dough once or twice, and then repeatedly roll it in the same direction as above described.

When such a sheet is submitted to the oven, the heat causes the disengagement of elastic vapor from the water and fatty matter, which being diffused between the numerous layers of dough, causes them to swell up, thereby giving that peculiar puffy construction to the baked material, which is a characteristic of this kind of bread. Although each layer is partly distended from the adjoining ones, yet the bread on the whole is not light, for the substance of each stratum is dense and hard of digestion.

Sesquicarbonate of ammonia has been used to a considerable extent in confectionaries, and also in making the finer kinds of bread. The salt, on being slightly heated, is broken up into carbonic acid, ammonia, and bicarbonate of ammonia, all of which are volatile. The powder is mixed with the flour, or dissolved in the water used to make the dough, and on subsequently kneading the flour with this saline solution, the salt gets pretty equally disseminated throughout the mass.

The dough, during the kneading, evolves the characteristic odor of ammonia; the taste is likewise peculiarly saline; but all these properties are lost during the baking, as their source is expelled by the heat. All the ammoniacal salt is not, however, driven off from the loaf, for a careful examination of the crumb will prove the presence of ammonia; yet the free alkali is disengaged, and, therefore, no pungent smell remains. The action of sesquicarbonate of ammonia is, in fact, more mechanical than that of the carbonic acid generated by yeast. By the use of sesquicarbonate of ammonia, many bakers palm upon the public bread made of inferior and often unwholesome substances, as being of good quality, in which case the use of the carbonates of ammonia, though harmless in themselves, are made the vehicles of criminal adulteration.

Carbonate of soda and hydrochloric acid are used, as already noticed, for raising the dough without destroying any part of the valuable constituents of the flour. The alkaline compound is mixed intimately with the flour, after which the proper quantity of hydrochloric acid necessary to neutralize the soda, is mixed with the water, and the dough made. This method was revived in 1848 by Mr. Sewell, who took out a patent for it. His process is to place the flour in a tub, or circular vessel, and to add thereto a quantity of hydrochloric acid—forty-five ounces avoirdupois, of specific gravity 1·14, containing about twenty-eight per cent. of real acid, to two hundred and eighty pounds of flour—by means of a series of radial tubes, whose bore is about one-hundredth of an inch, and from which it falls in a finely-divided shower, while fresh surfaces are continually being exposed to the acid till the whole is thoroughly mixed. The flour thus prepared is designated No. 1. He prepares No. 2 flour by mixing, at the point when the proportion of acid has been incorporated as in No. 1, about thirty-nine ounces of bicarbonate of soda in fine powder with every pack of the flour of the above weight. The soda is intimately comminuted by sifting, and when this process has been repeated two or three times, it is ready for use. All that is required to make this flour into bread, is merely to knead it with the proper amount of water, and put it into the oven, which should have a brisk heat. The flour is said to keep for a month. The No. 1 flour of Sewell will keep no longer than five weeks. For making this into bread, it is merely required to proceed as before, except that, if it be used in small portions, the weight of the soda salt is to be proportioned to the weight of flour used, and which, according to the patentee, is sixty-three grains to the pound. In both instances, cold water is directed to be used in kneading the flour, and the dough, if not put immediately into the oven, should be retained in as cool a place as possible; it should never remain longer than one or two hours at most from the time of working, till it is put into the oven.

The carbonic acid liberated in the chemical decomposition, which is produced between the soda salt and the acid, is the means employed for distending the dough; this decomposition may be represented as follows.—

$$\underbrace{\mathrm{Na\,O,\,2\,C\,O_2}}_{\text{Bicarbonate of soda.}} + \underbrace{\mathrm{H\,Cl}}_{\text{Hydrochloric acid.}} = \underbrace{\mathrm{Na\,Cl}}_{\text{Chloride of sodium.}} + \underbrace{\mathrm{2\,C\,O_2}}_{\text{Carbonic acid.}} + \underbrace{\mathrm{H\,O}}_{\text{Water.}}$$

Many medical men object to this method of baking, as it is calculated to introduce more chloride of sodium into bread than is deemed necessary for the health of the consumers. Hassall remarks:—Although its use in moderate quantity with meat is a general custom, and probably a salutary one, yet its effects upon the human system are by no means so clearly ascertained as to justify its employment in very large quantity, in so important an article as bread.

Bicarbonate of soda and tartaric acid, mixed in equivalent proportions, are other substitutes for yeast. The result of their action is the same as the preceding; instead of chloride of sodium, however, tartrate of soda is formed. This mixture of bicarbonate of soda and tartaric acid is retailed by druggists under the name, *baking powder;* the Editor finds it to consist of equal weights of the ingredients, intimately mixed by grinding in a mortar. In preparing a dough with this compound, it is thoroughly mixed with the flour by agitation and sifting; the usual quantity of water is then added, and the whole quickly stirred and mixed up into the form of the loaf; as soon as the water comes in contact with the flour, with which the mixture has been incorporated, carbonic acid is liberated, on account of the chemical action consequent upon the solution. In making this kind of dough, the hands cannot be conveniently used in the usual way, as the moist flour adheres to them, and therefore a mechanical agitator or wooden spatula should be employed; and when the mass has acquired sufficient consistency without any lumps of dry flour being allowed to remain, it is shaped, put into the moulds or otherwise, and baked as speedily as possible. One tea spoonful of the baking powder is sufficient for each pound of flour.

A patent has been taken for a mixture of flour with other ingredients, having for its object the making of bread in a ready manner. Take wheat, or other grain from which flour is made, of fine quality, perfectly dry. After grinding and dressing, it should be allowed to ripen for about six weeks; then to each hundredweight put ten and a half ounces of finely-powdered tartaric acid of the best quality, and as dry as possible; mix it well with the flour, and pass the whole through a dressing machine; after which, allow it to remain untouched for two or three days, that the constitutional as well as any mechanical water present in the tartaric acid may be absorbed by the flour, and so form around the particles of acid a coating that will prevent immediate contact with the alkali, without which precaution decomposition would ensue; afterwards incorporate with the flour and dry acid twelve ounces of bicarbonate of soda, twenty-four of chloride of sodium, finely powdered and dry, and eight of ground loaf sugar; mix the whole well, and pass it through a flour dressing machine, when it will be ready for use.

Many other compounds, of similar constitution to those mentioned, have been used as substitutes for yeast.

The bread made from flour mixed with tartaric acid and bicarbonate of soda, has a whiter color than that made with yeast; it is, however, very plastic, and wanting in that lightness and spongy texture which characterizes well-made fermented bread.

It has been stated, that by kneading flour with water surcharged with carbonic acid, good piled bread may be made. Such statements are evidently at variance with facts. Dr. COLQUHOUN long since proved, that not only dough made in this way, but also that made by admixture with the aforesaid chemical compounds, is inferior to that which results from the use of yeast or ferment. From the circumstance that those mixtures evolve the aerial body too rapidly, and from the want of that elasticity which kneading confers, the gas freely escapes, as well before introducing it into the oven as after, and the consequence is the formation of a heavy loaf.

The experiments of VOGEL amply prove, that properly piled bread cannot be formed by the preceding means, as when the mass of dough was kept during the usual period which yeast bread takes to rise, before introducing it into the oven, nothing better than a tough amorphous plastic mass was obtained. The same chemist states, that it is necessary to have the volume of gas generated in the dough previous to its being put into the oven. To prove this he made the following experiment: fine iron filings were mixed with the flour, which was then kneaded with dilute sulphuric acid, to disengage gaseous hydrogen on the application of heat. The result was quite unsatisfactory, as the loaf when baked appeared plastic and heavy. Similar results were subsequently obtained by COLQUHOUN.

BISCUIT-MAKING.—This is a branch of bakery which has of late advanced considerably, particularly in large trading seaport towns; the business has been also pursued in the provincial districts, but in such places attention is chiefly directed to the preparation of fancy articles. The most extensive biscuit factory in England is the Royal Clarence Victualling Establishment at Portsmouth, which is competent to supply the whole naval staff. The proper method of making biscuit to meet the large consumption of the naval force, as well as for the naval trade, was a great desideratum. The old mode of biscuit-making was laborious, inconvenient, and uncleanly. At Gosport, where nine ovens were at work on this plan, there were five men attending each oven; these had each his own peculiar work, and they were named accordingly; *videlicet*—the *turner*, the *mate*, the *driver*, the *breakman*, and the *idleman*. When in operation, the requisite quantity of flour and water was put into a trough, and the driver, with his hands, mixed the whole up into dough. This was next taken from the trough and put on a wooden platform called the break, whereon a lever, five or six inches in diameter, and seven or eight feet long, called the breakstaff, was supported; one end of it was loosely attached by a kind of staple to the wall, and the breakman, riding or sitting on the other extremity, worked this lever to and fro over the dough, by an uncouth, shuffling movement. When the paste had become kneaded by this singular and often disgusting method into a thin sheet, it was removed to the moulding-board, and cut into slips by means of an enormous knife; these slips were then broken into pieces, each large enough to form one biscuit, and then worked into a circular form by the hand. Each biscuit, after being shaped, was handed to a second workman, who stamped the king's mark, the number of the oven, *et cetera*, upon it, after which it was *docked*, or pierced with holes, by an appropriate instrument.

The finishing part of the process was one in which remarkable dexterity was displayed. A man stood before the open door of the oven, having in his hand the handle of the peel, the other end of which was lying flat on the oven; another man took the biscuits as fast as they were formed and stamped, and jerked or threw them with such undeviating precision that they fell exactly upon the peel, and were then arranged by the man holding it, all over the bottom of the oven. In manual labor, the regularity with which this was done could not possibly be exceeded. Seventy biscuits were thrown into the oven and properly arranged in one minute, the attention of each man being vigorously directed to his own department, for a delay of a single second on the part of any one would have disturbed the whole. Biscuits do not require many minutes' baking, and as the oven is kept open during the time that it is being filled, the biscuits first thrown in would be overbaked were not some precaution taken to prevent it. The moulder, therefore, made those which were to be first thrown into the oven larger than the subsequent ones, and diminished the size by a nice gradation.

The machinery for the preparation of biscuits, invented by Mr. GRANT of the Royal Clarence Yard, consists of a trough wherein a shaft, to which a number of knives is appended, works with great rapidity, in order to mix the flour or meal and water into biscuit dough; two cylinders, of about fifteen hundredweight each, the first of which is called a break-roller, and serves to knead the dough, and the second to spread the paste kneaded by it to the proper thickness of the biscuit before it is cut; all of these are worked by steam. The break-roller is erected upon a stout table, and by means of suitable machinery can be raised and depressed at pleasure. A heap of the dough from the kneading-trough is placed at one side by two attending workmen, and the roller being temporarily elevated, the dough is pushed under it, when it is again brought down and set in motion; by this means the mass is flattened into a sheet, and carried to the other side. By reversing the motion of the roller, and lowering it still further, the sheet is rolled back, where the workmen receive it and fold it up in breadths; it is afterwards subjected three times successively to a similar pressure. As the dough is discharged from the roller the third time, it is about two inches thick, and is then cut by the attending workmen into pieces about half a yard square The operation with the break-roller occupies about five minutes, the dough being kneaded much better than if done by the hand. The second roller spreads out the squares of dough produced by the first operation to the size of six feet by three, to bring the sheet to the thickness of the biscuits, which are shaped by the cutting or stamping press. The under surface of this press is composed of a series of sharp knives of a hexagonal shape, which cut a piece of dough a yard square into sixty biscuits of a similar form. In some manufactories, the stamping or cutting of the biscuit is effected by a roller having the knives arranged circularly; in this case, however, the sheet of biscuits cannot be immediately introduced into the oven, as there is a space between each circle, and the biscuits have to be picked out separately, and laid upon trays. When the hexagonal arrangement is employed, there is no waste of either time or material in this point, as the cakes fit accurately into each other. In either case, they are introduced as soon as possible into the ovens, which are very spacious, and heated either by hot air, or by a continuous fire, the flues from which pass under and over the baking compartment: in the course of ten to fifteen minutes they are taken out.

A biscuit-oven, on a new principle, was patented by Mr. William Slater, of Carlisle, in December, 1852. It consists of an earthenware tube or retort, set in brickwork, and traversed by a series of endless chains, or some other flexible fireproof material, by which the biscuits are carried on trays, the tube being heated by a fire or furnace below. The biscuits are made to travel slowly from end to end of the tube, which is of considerable length, so as to allow of their being completely baked during the passage. The oven is thus entirely self-acting. A pyrometer is attached externally, so that the attendant can regulate the heat with great precision and facility.

Fig. 244 is a longitudinal, and Fig. 245 a transverse section of the oven. A A is the earthenware tube in which the biscuits are baked: it is shaped somewhat like a gas retort, and should not be less than sixteen to twenty-four feet in length. It is set in brickwork, like a steam-boiler, and is heated by the furnace, B, which is supplied with fuel in the usual way. The overhead brick or clay arch, D, receives the direct radiant heat of the fuel, and the heated gases pass off from the grate along the bottom flue, C, in the direction of the arrow, running hence beneath the tube, A, and rising through the lateral passages, E, which branch off from the furnace and main bottom flue, into the side and overhead flues, G. After traversing all the flue lengths, the heated current passes off through the chimney, H. The tube, A, is thus completely enveloped in a heated medium. It is open from end to end, but is covered in at each extremity by iron plates, I, slotted through to permit the passage of the endless carrying band or chain, J. This band or chain revolves on two external rollers or pulleys, K, and in passing through the tube, both the upper and lower lengths are supported by a series of bearing rollers, L. This carrying apparatus may either be composed of two parallel endless chains, with carrying trays laid across, or of a series of trays so connected as to form an endless chain; or it may simply consist of an endless web of wirecloth. One of the pulleys, K, being made to revolve at the required rate by means of any convenient prime mover, the chain, with the biscuits laid on, is traversed through the tube, the speed of movement being regulated so that the biscuits shall be baked to the required extent in the transit. The baking heat, which is, of course, derived from all sides of the heated tube, A, is capable of nice regulation, by means of dampers suitably disposed in the flues. The pyrometer, or heat indicator, consists of a copper rod, M, stretched along the upper side of the tube. It is fixed at the back end, but its other end passes through the plate, I, where it is fixed to a stout helical spring, contained in the box, P, and contrived so as to hold the rod, M, in a high state of tension. To protect the spring from the heat of the box, the latter is lined with loam or sand, or is made of baked wood. The end of the rod has a transverse pin attached to it; and this pin works through a longitudinal slot in the box, being made to act upon an arrangement of multiplying levers, terminating in an index-hand, R, which points to the degrees of temperature marked upon the outside of the plate, I. The rod, M, is supported in its length, either by pendant links hung from above, or by two other metal rods passed through the oven, with cross bearers at intervals. This contrivance is now in full operation at Mr. Slater's extensive biscuit works in Carlisle.

Fig. 244.

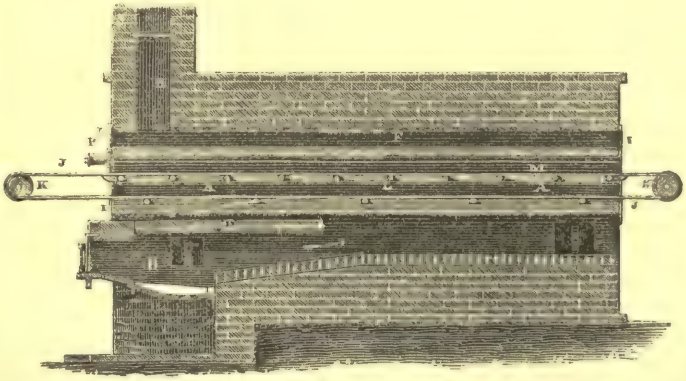
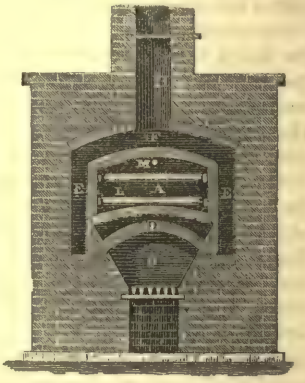


Fig. 245.



The following is an account of the baking establishment at Weevil, near Portsmouth.

It having been discovered that the flour supplied to Government by contract had, in many instances, been seriously adulterated, the corn is ground at mills connected with the establishment, by which means the introduction of improper ingredients is prevented, and precisely the proportion of bran which is requisite in the composition of good sea biscuit is retained.

The flour mill is furnished with ten pair of stones, by which forty bushels of flour may be ground and dressed ready for baking in an hour. The baking compartment consists of nine ovens, each thirteen feet long, eleven feet wide, and seventeen and a half inches in height. These are each heated by separate furnaces, so constructed that a blast of hot air and fire sweeps through them, and gives the requisite heat in an incredibly short space of time. The first operation in making the biscuit consists in mixing the meal and water; thirteen gallons of water are first introduced into the trough, and then a sack of the meal, weighing two hundred and eighty pounds. When the whole has been poured in by a channel communicating with an upper room, a bell rings and the trough is closed. An apparatus consisting of two sets of knives, each series ten in number, is then made to revolve amongst the flour and water by means of machinery. This mixing operation lasts one minute and a half, during which the knives or stirrers make twenty-six revolutions. The next process is to cast the lumps of dough under what are called the breaking-rollers—huge cylinders of iron, weighing fourteen hundredweight each, and moved horizontally by machinery upon stout tables. The dough is thus formed into large lumps six feet long, three feet broad, and several inches thick. At this stage of the business the kneading is very imperfect, and traces of dry flour may still be detected. These masses are now drawn out and cut into a number of smaller ones, about a foot and a half long and a foot wide, and again thrust under the rollers, which is repeated until the mixture is so complete that not the slightest trace of any inequality can be detected in any part of the mass. It should have been stated, that two workmen stand, one on each side of the rollers, and as the dough is flattened out, they fold it up, or double one part upon another, so that the roller in its progress squeezes these parts together and forces them to mix. The dough is next cut into small portions, and being placed upon large flat boards, is, by the agency of machinery, conveyed from the centre to the extremity of the baking-room. Here it is received by a workman, who places it under the *sheet-roller*. The kneading is thus complete, and the dough only requires to be cut into biscuits before it is committed to the oven. The cutting is effected by the cutting-plate, consisting of a network of fifty-two sharp hexagonal frames, each of the size of a biscuit. This frame is moved slowly up and down by machinery, and the workman, watching his opportunity, slides under it the cake of dough; the cutting-frame in its descent indents this sheet without dividing it, but leaving sufficient substance to enable the workman at the mouth of the oven to jerk the whole mass of biscuit unbroken into it. The dough is prevented sticking to the cutting-frame by the following ingenious device. Between each of the cutter-frames is a small flat open frame, movable up and down, and loaded with an iron ball weighing several ounces. When the great frame comes down upon the dough, and cuts out fifty-two biscuits, each of these minor frames yields to the pressure, and is raised up; but as soon as the great frame rises, the weight of the balls acting upon the smaller frames, thrusts the whole perforated sheet off, allowing the workmen to remove it. One quarter of an hour is sufficient to bake the biscuit, which is afterwards placed for three days in a drying room heated to from 85° to 90° Fahr., which completes the process.

URE gives the following statement, showing the advantage and saving consequent on this method of baking biscuits. In one hundred and sixteen days, during sixty-eight of which the work was continued for only seven and a half hours; and during forty-eight, for only five and three-fourth hours each day; in all, seven hundred and sixty-nine working hours, equal to seventy-seven days of ten hours each; twelve thousand three hundred and seven hundredweight, equal to one million three hundred and seventy-eight thousand four hundred pounds of biscuit, were baked in the nine ovens. The wages of the men employed in baking this quantity amounted to £273. 10s. 9½d.; if it had been made by the hand, the wages would have been £933. 9s. 10d.; thus a saving in wages of £659. 19s. 0½d. was effected. In this is not included any part of the interest of the sum laid out upon the machine, or expended in keeping it in order; but in a very short time, at such an immense rate of saving, the cost of the engine and other machinery would be amply counterbalanced.

FANCY BISCUIT BAKING.—This branch, which was heretofore confined to retail confectioners, has latterly acquired an importance entitling it to be ranked among the minor staple commodities of the kingdom; for not only does the home demand absorb thousands of tons weight annually, but large quantities are exported to the colonies and foreign countries. This change, like many others of modern date, has been brought about by means of the manufacturing system; which, by its subdivision of labor, the skilful adaption of machinery, and capabilities of production on an extended scale, has so diminished the cost as to place within reach of the million what was till of late years a luxury for the opulent. The production of fancy biscuits on the large scale mentioned, is confined to some half dozen localities. In Liverpool, the eminent establishment of Messrs. HAYLOCK and COMPANY, is conspicuous; and in Carlisle, those of Messrs. CARR, and Messrs. SLATER and COMPANY; and in London, Mr. LEMANN'S is the most famous.

In this department, one is struck with the variety of form and names of the products; so numerous are these, that no less than *sixty* sorts are made, all reputed to be different, and what is most singular, every new kind seems for a season to take the place of its predecessors. This, if it augurs nothing else, at least indicates a love of novelty, which the trade tampers with to a vast extent; for large sums are yearly expended in procuring designs, as well in the form as in the manner in which the biscuits are presented to the public. These articles may be divided into three classes:—

Water, or Hard Biscuits, into the composition of which butter, eggs, sugar, and spices, occasionally enter.

Yeast Biscuits, or such as undergo a partial fermentation, and

Soft Biscuits, containing larger quantities than the foregoing of butter and sugar.

In all the subdivisions of these classes the components are nearly identical, but the proportions vary. No fixed general rule is followed, as every manufacturer endeavors to keep pace with, or flatter the caprice of the consumers; hence it would be preposterous to expect in an article like the present that anything beyond a resumé of the usual routine could be laid before the reader. Such information is, however, offered as will contribute to the production of a good and delicate preparation. Of the hard or water biscuits, the principal kind, and from which the others have diverged, have been already described in speaking of ship bread. Those of the same order relished by the community are principally captain, machine, Abernethy, American, coffee, Jamaica, and lemon biscuits. All these differ very little from one another in composition, as may be seen from the annexed table, proportioned to the sack of 280 pounds:—

	Water or milk. quarts.	Butter. pounds.	Eggs	Sugar. pounds	Flavorings. ounces.
Captains,	10	15	—	—	—
Abernethy,	8¾	17½	—	17½	17½ Carroway seeds.
Machine,	5¾	58	—	14	—
American,	10	40	—	—	—
Coffee,	8¾	17½	140	—	—
Jamaica,	8¾	17½	—	17½	—

The butter is intimately mixed with the flour in the dry state, and then the water or milk in which the sugar may be dissolved, added, and the whole made into dough by a kneading machine, similar to those already mentioned under BREAD. The operation of kneading is usually performed in the higher stories of the factory, and the lumps of dough let down to the rolling or flattening cylinder, where they are elongated into a sheet of the appropriate thickness, and then docked with the peculiar moulds.

By a very ingenious contrivance working at HAYLOCK and COMPANY'S, as soon as the biscuit is shaped out, it is placed at once, by the apparatus, upon the baking-tin, and conducted into the oven. Thus, the necessity of bringing the hands of the workmen in contact with the dough is obviated, which is an important consideration. The baking is performed by a no less ingenious method than the above, in ovens that are continuous in their operations, and the invention of which, the Editor is informed, belongs to the last-mentioned manufacturers, who find them to perform the work most satisfactorily, and they have now had them in active operation for a number of years. The oven may be said, in general, terms, to consist of an iron tube or box, which may be from ten to thirty feet in length, two to eight in width, and one to two in depth; through this an endless series of iron plates, on which the biscuits are deposited, is made to travel, and the speed is so regulated, that during their progress through the tube, they are properly baked.

Heat is communicated by one or more furnaces, the flues of which are carried under and over the tube. As the heating is wholly external, the baking can be continuously carried on, and, moreover, as no deleterious gases enter the oven, the biscuits produced possess a purity never obtained by the old processes.

The temperature of the oven is an important point with the biscuit artificer, as a great deal of his success depends upon this being rightly maintained. This is always such as to give the materials a nice brown color without burning them. Biscuits containing much sugar should not be raised to so high a heat as those which are without it, because it would be apt to be caramelized, destroying the beauty of the product. The time usually required to bake the above kinds is variable, from ten to fifteen minutes at the longest.

To give additional lightness, it is the practice of some to add a little sesquicarbonate of ammonia, or *volatile salt*, as it is termed, but this is more employed in the yeast biscuits, or those the dough of which is subjected to fermentation.

Of the yeast biscuits, those which seem to be preferred are Oliver, Reading, and Cheltenham, but several other kinds of this class are made. The materials of the three above-mentioned may be taken as shown in the subjoined table:—

	Flour. pounds	Dried yeast. pounds.	Water or milk. gallons.	Butter. pounds.	Sugar. pounds.
Oliver	280	4½	10½	35	—
Reading,	280	4½ to 5	—	25 to 30	—
Cheltenham,	280	—	10½	—	5

The third class, usually termed *soft*, are numerous, and are generally rich in butter and saccharine matter, as well as in albumen, in consequence of the quantity of eggs which is used to give them a full flavor, and a deep rich cream color. Spices and essences are added to suit the taste of purchasers. For inferior biscuits, tartaric acid and supercarbonates of soda or ammonia are employed, to give the lightness which the butter communicates to the better variety; and chromate of lead—chrome yellow—is used, by the lowest class of makers, as a substitute for the eggs. These, and many other substances which are deleterious to the consumer, should be avoided. Subjoined is the ordinary composition of some of the products of this kind in highest repute:—

	Flour.	Water or milk.	Butter.	Sugar.	Eggs.	Flavorings.
Tunbridge cakes,	280	—	23	140	930	Orange flower water.
Tunbridge currant, citron, and carraway,	—	—	—	—	—	With these substances.
Shrewsbury,	280	—	93	93	93	2½ Volatile salt, nutmeg, cinnamon, or mace.
Ginger wafers,	280	—	112	112	600	Ginger.
Victoria biscuits,	280	—	80	70	750	Essence of lemon or neroli.

All these kinds, which are only a fraction of what are made, require peculiar care in the manipulations: the eggs and sugar finely ground, are beaten together at a temperature of 100° Fahr., till the mixture has a pasty appearance, and is distended with air bubbles. The flour and butter are then mingled together in the dry state, and the egg paste incorporated with it by suitable means. The flavorings are added either in the form of powder, or their extracts or essences; the latter are, however, employed with better success.

On the whole it will be seen that in all the details above given of the various kinds of biscuits, there is a striking similarity in the components, the only difference being the variation in the proportions. Of course, this being the case, a man practically acquainted with the routine of the business, can produce, by altering the constituents, almost any variety of biscuit *ad libitum*.

To give the reader a faint idea of the extent to which fancy biscuits are now manufactured, it may be sufficient to state that the firm of Messrs. HAYLOCK and COMPANY, which has, for a long period been celebrated for the beauty and excellence of its products, affords constant employment to upwards of one hundred persons, and fabricates from twenty-five to thirty thousand pounds weight of fancy biscuits each week.

Adulteration of Bread.—It may well be stated that no other article, the manufacture of which has risen to any extent, has been subject to such open and flagitious adulterations as bread. This is no idle or unfounded assertion, but one which has been repeatedly proved by well-ordered researches and examinations conducted by competent persons.

These adulterations continue in some measure to be practised in spite of science, which is, nevertheless, constantly bringing to light the hidden deeds of darkness, and holding up to the comprehension of the uninstructed, in a clear and unmistakeable picture, the danger of having such ingredients mixed with their daily sustenance.

As a zealous devotee in this cause, the Editor will endeavor to lay open such impositions to his readers, hoping that it will put them on their guard, and, at the same time, be a means of preventing the continued commission of this audacious crime.

The adulterations of bread are of two kinds: the first is the mixing of fine flour with that of an inferior quality; the bread made from this compound being sold as of the best description. This system, though in itself highly wrong, is not of so black a character as the next, which consists in adding deleterious compounds, to give a white color, and oftentimes also to increase the density or specific gravity.

Mouldy flour, the flour of rye, barley, oats, beans, and rice, and sometimes potatoes, in a boiled and crushed state, constitute the first species of adulteration; some of them are used for their cheapness, while others add to the weight of the bread by retaining larger quantities of water than good bread holds, and thus the baker who sells such bread *by weight*, gains considerably. In both cases, the bread is injured in quality, and the consumers are cheated. It should be observed, however, that the bakers are not to be exclusively identified with this imposition, for it is well known to the Editor that flour, when purchased from millers and corn merchants, has often been highly sophisticated with one or other of the foregoing.

To give a laborious method for the analysis of flour would be out of place here, more particularly as it could not be well performed by any save competent chemists; and the cost of such an investigation would prove an insuperable obstacle to the honest trader, who might be disposed to give a good and wholesome article to the public. In order to put within the reach of even the working baker the means of making a sufficiently accurate analysis of his flour, by which he can form an estimate of the average purity and worth of the article, the Editor draws attention to the following method of M. Boland, an intelligent baker of Paris, as quoted by Dumas:—

Twenty grammes—equivalent to rather more than half an ounce—of flour are treated by the ordinary process for extracting the gluten, but taking care to collect all the amylaceous liquid in a large glass, conical at foot; it is left to settle for two and a half or three hours, and then the whole of the clear supernatant liquid is decanted.

The operator then removes with a teaspoon all the upper, soft, greyish portion of the sediment, which contains the wheat starch, albumen, and gluten, without cohesion.

The small mass which has settled at the bottom of the glass, exhibits the consistence of deposits of pure starch, or of *fecula;* it is left in a state of rest till it becomes sufficiently solid to be taken up in a lump, by pressing the finger against the side of the glass. The rounded portion which forms the summit of the small conical mass, containing the first portions deposited, will be the richest in potato starch, if there has been any mixture of this in the sample submitted to trial. The next operation is to separate with the edge of a knife about one gramme from this portion, and then, having rubbed it up in an agate mortar with a little water—diluted it with more water, and filtered—the clear filtered liquid will be colored blue by a solution of iodine, if any potato starch has been used. According as this phenomenon is reproduced on a second layer of one gramme, removed by a section parallel to the first slice, then on a third, *et cetera*, the operator concludes that the flour contains nearly one, or two, or three-twentieths of its weight of potato starch.

If the first slice taken from the summit of the small *cone* gives, after trituration, a liquid which, when filtered, is not sensibly colored blue with iodine, or which takes a light violet reddish tint, soon disappearing spontaneously, it may be inferred that the flour has not been adulterated with the article under notice.

The method just pointed out, and some others, enable the operator easily to detect the presence of potato starch in flour; but as regards the proportion of the mixture, no simple process has as yet been discovered which can be fully relied on for indicating this with precision. The foregoing difference between the starch of the potato and that of wheaten flour, is due to the action of the mortar and pestle, by which the starch granules of the former are broken, and the liquid matter eviscerated, while the wheat starch remains unaffected. A glass or procelain mortar should not on any account be employed, as the coarseness of these would rupture the granules of wheat starch, and the reaction would not answer the proposed end. If the potatoes had been added to the wheat before grinding, its detection by the iodine test, as just mentioned, cannot so well be relied upon as when fecula has been employed *after* the grinding. So long as the amount of starch does not exceed ten per cent., the fraud is attended with too little profit to cause much apprehension, but beyond this limit it merits attention.

When mixed in the proportion of thirty per cent., the process of purification becomes impossible. With regard to the gluten, M. Boland proposed a test to ascertain, with ease and accuracy, both the proportion and its chief qualities. He weighs exactly fifty grammes of the flour to be examined, and puts them in a capsule. On the middle of the little heap of flour, he pours about twenty cubic centimetres, or twenty grammes of water, mixes both with a spoon or spatula, and thus obtains a plastic and highly consistent mass. It is then kneaded between the fingers for two minutes, and the hydration is left to be completed in a state of rest for a period of fifteen minutes in summer, and one hour in winter. Having then immersed a fine metallic sieve in five or six litres, or about two and a half gallons, of cold water, the dough is dipped for an instant carefully, and for several times, into the water of the sieve, working it without ceasing, at first slowly, and then quicker by degrees. By a little practice, the whole of the starch and soluble matter can, in this way, be entirely disseminated in the water, whilst the adhesive particles of the gluten remain united in the pliable elastic mass that is left in the hand. It is proper to ascertain, by raising the sieve, whether any fragments of the gluten have escaped, which may be reunited to the mass; the washing is finally accomplished by working it briskly for ten minutes in a stream of cold water. The gluten obtained is strongly pressed, then wiped, afterwards weighed, and introduced into the oven, where it quickly dries; before it has been acted upon by the heat so as to produce a brownish color, it is withdrawn, to be again immediately weighed. The proportion of moist and dried gluten is thus found; but they mutually depend on each other, as if any foreign ingredients, such as ten to fifteen per cent. of potato flour, were added, the weight of gluten, both in the moist and dry state, would be proportionally less than what genuine flour would afford.

M. ROBINE, proceeding on the solubility of gluten in acetic acid, proposed an instrument, which is no other than an areometer, to determine the number of loaves which any particular kind of flour would furnish. A sack of flour, weighing one hundred and fifty-nine kilogrammes, or three hundred and forty-eight pounds, ought to yield from one hundred and one to one hundred and four loaves of two kilogrammes, or four pounds six ounces each. The areometer which he employs indicates the number of loaves above or below this limit. The process is conducted at 59° Fahr., with water charged with acetic acid, distilled till it indicates 93° on the special areometer. If the flour is fine, twenty-four grammes of it are taken, and twelve-sixteenths of a litre of the liquid acid; they are mixed, and left to settle in a conical vessel. If the flour is of poor quality, thirty-two grammes are used, and one quarter of a litre of acetified water.

At the end of one hour the starch settles at the bottom of the vessel, and the bran produces a layer above it. The milky liquid which floats above contains the gluten, and is covered with a frothy scum, which may be removed with a spoon.

Dipping M. ROBINE'S areometer into the liquid decanted off, and maintained at the temperature above named, the instrument will indicate the number of loaves which the sack of flour should yield.

This process is attended with some chances of error, proceeding either from the presence of salts or soluble matters, such as dextrin, which might have been added to the flour, or from the alteration of the gluten.

These methods would, in every case, be insufficient to determine the value or the purity of a flour, tried without reference to some object of comparison; for [illegible] the different kinds or varieties of corns, white or [illegible]form semihard and hard, or horny, the gluten varies in the proportion of 0·8 to 0·20 and more.

But the nature of the gluten may, in all cases, furnish useful indications with regard to the quality of the meal; the more tractable it is, the more elastic, tenacious, ductile, homogeneous, and free from a bad smell and brown color, the better is it raised by its rapid desiccation in the oven, and the more probable is it that the flour from which it proceeds is of good quality.

There are several changes in the corn and flour themselves, especially arising from germination in the sheaf or stack, from fermentation of the moist grain, or even of the meal, which alter the qualities of the gluten. Without changing its chemical composition, or doing so only in a slight degree, it becomes less elastic and partly soluble; in that case it rises much less by the disengagement of the vapor, its color is or appears to be browner, and its smell is often disagreeable.

In damaged flour, the gluten has been known to disappear entirely, and to be replaced by ammoniacal salts. In that case lime disengages ammonia from it without heat. In a less advanced state of alteration, the gluten is only deprived of its elasticity, and becomes more or less soft. It is, therefore, of great importance to apply the gluten test pointed out by M. BOLAND. It consists in placing the gluten at the bottom of a copper tube, which may be heated in the oven. From the length of the tube which the gluten occupies in swelling, its quality is determined. If it be not convenient to heat the tube in the oven, the proper temperature may be communicated by an oil-bath, raised to 284° Fahr.

Rye, barley, and oat flour are difficultly detected, and only the practised microscopist can discern them, except they be present in large quantities. By attention to the preceding test, however, the baker may ascertain the value of the gluten which a definite weight of flour affords, and from this datum judge of its quality. Dr. HASSALL gives the characteristics of rye starch corpuscles as follows:—

The starch granules of rye bear a general resemblance in form and size to those of wheat; there are, however, these remarkable and satisfactory differences, *videlicet*, that the lesser grains are decidedly smaller than the corresponding grains of wheat, and that many of the larger granules of rye starch are furnished with a three or four rayed hilum.

The presence of barley flour is difficult of discovery, unless by the aid of the microscope. If it be present in large quantities, however, it can be ascertained by treating a portion of the suspected flour for some time with boiling water, when, if the adulterant be barley flour, an insoluble starch remains. Wheat flour leaves some insoluble matter when similarly treated; the quantity is, however, considerably less than what the barley flour affords. To give additional security to the experiment, it would be well to take an equal weight of *genuine* wheat flour, and treat it similarly to that suspected, and from the comparative bulk of the insoluble substance from each, it may be readily decided whether barley flour be present. The flour of maize or Indian corn may be detected by washing the mixture under a thin stream of water, or by agitating the flour in a fine wire sieve suspended in water, in order to remove the starch from the gluten, and examining the glutinous residue with a microscope or magnifying glass; semitransparent fragments of an angular shape will be observed, if maize or rice be present. When the flour of maize or rice is mixed in any considerable proportions with wheat flour, the bread is harsh and dry; if Indian corn is used to any extent, it communicates a distinct yellow tinge, and feels coarse; it has, moreover, a peculiar sweet flavor.—*Normandy.*

Bean flour is often employed by bakers, partly for the sake of the rich yellowish and highly esteemed tint which it imparts, but the bread acquires from it a rose tinge which betrays the fraud. It may be detected by submitting a portion of the flour to dry distillation, and collecting the distillate; if this liquid be examined, it will be found to have an alkaline reaction in a greater or less degree, according to the proportion of the adulterant. The same indication is given by the ground pulse and peas; genuine wheat flour affords no such reactions when similarly treated. **NORMANDY** gives the following process for the detection of the adulteration:—

Take of the flour for examination,........ 300 grains,
" sand,........................ 300 "
" water,...................... 2 ounces;

Triturate the flour and sand strongly for about five minutes in a Wedgwood-ware mortar, and add the water gradually, by small portions at a time, so as to form a homogeneous paste, which should then be diluted with the remainder of the water. On filtering, it will be observed that the substance, if it contains bean flour, percolates much more slowly than when the same experiment is tried with genuine flour, and remains milky. A portion of the filtrate should then be mixed with its own bulk of a solution of iodine, prepared expressly for the experiment. The liquor filtered from pure wheat flour, being tested by the solution of iodine, assumes a deep pink color, but that which has been obtained from the flour under examination gives a lighter hue, and is more permanent than the other.

The second species of adulteration to which reference was made in the preceding, and which is said to have been once extensively followed, though the Editor thinks it is now almost entirely abolished—for the fraud is too palpable to pass unnoticed in the nineteenth century—is the admixture of various mineral compounds with the flour, for the purpose of increasing its weight. The substances prepared for this purpose and here referred to, are chalk, bone earth, calcined flints ground, plaster of Paris, pipe-clay, and similar bodies; all of which, from their whiteness, might and did escape the observation of the inexperienced consumer. These may be detected as follows:—A quantity of the suspected flour is taken, and if it be desired to estimate the extent of the adulteration, it is weighed, then burned in a platinum dish, or one of porcelain if the former be not at hand, till all the carbonaceous substance has been consumed; the weight of the residue will afford a sure criterion as to whether the flour be adulterated or not. Genuine flour, as may be learned from what was stated near the commencement of this article, affords from one to one and a half per cent. of ash or mineral constituents, and if the residue left in the experiment above mentioned should greatly exceed this, it is a plain proof of the adulteration. By a preliminary examination of the residue, the nature of the mineral ingredients may be known. Acetic acid, when poured upon it, will cause brisk effervescence, if chalk or carbonate of magnesia be present, and if the liquid be filtered off and examined with ammonia, chloride of ammonium, and oxalate of ammonia, the formation of a white precipitate is a sure indication of the presence of lime; should no precipitation, however, take place upon the addition of the oxalate, but a flocculent one should appear upon pouring in phosphate of soda, it indicates the presence of magnesia. By treating the residue remaining, after the action of acetic acid, with hydrochloric acid and boiling, phosphate of lime is thus dissolved; if sand or clay be present, it remains insoluble. It may be ascertained whether the residue is wholly clay or sand by heating it on charcoal, moistening the mass with a drop or two of nitrate of cobalt, and submitting the assay again to the temperature of the interior blowpipe flame, when, if the substance be clay, a blue color is produced.

Gypsum—plaster of Paris—is detected in flour, by washing a portion with water, collecting the washings, and pouring them into a conical glass, as directed in the foregoing under potato starch; the sulphate of lime being denser, will fall to the bottom more readily than the starch, and will, therefore, constitute the under layer. As soon as the whole of the starch has subsided, the clear liquid is drawn off, and the glass placed in a warm situation so as to dry the sediment, which is then turned out of the glass. It will be readily seen, upon examining the cone, whether the lower part is constituted of sulphate of lime or not; and it may be proved by cutting off that part, and boiling it with a concentrated solution of carbonate of soda, which effects the decomposition of the sulphate, by giving rise to the formation of carbonate of lime and sulphate of soda. If the liquid be filtered off and examined with chloride of barium, it will afford a white insoluble precipitate of sulphate of baryta, showing the filtrate to contain a soluble sulphate; further, by treating the residue on the filter with hydrochloric acid, effervescence will be observed from the solution of the carbonate of lime, formed by the action of the alkaline carbonate; and by adding ammonia and oxalate of ammonia to the filtered liquid, a white precipitate of oxalate of lime falls; these experiments combined, show that gypsum was the adulteration. Bone earth is detected by treating a fresh portion of the flour with hydrochloric acid, and filtering; phosphate of lime dissolves out, and may be ascertained by adding a few drops of sesquichloride of iron, and then ammonia carefully, to neutralize the acid; if a white precipitate falls, it proves the presence of phosphoric acid.

The reader's attention will now be directed to the further adulterations of bread by substances, in the introduction of which the baker is supposed, and often justly so, to be instrumental.

Besides those bodies already enumerated, the substances which the baker employs are—

Alum.
Sulphate of copper.
Starch.
An excess of water.
Carbonate of magnesia.
The alkaline carbonates.

The Editor can have no object in implicating any person, or class of persons; but, from his own experience, together with what has been elicited from the able researches in the *Lancet* and other journals, he feels justified in saying, that a large proportion of bakers *do* adulterate their bread. The intention with which this is done is twofold: firstly, to pass off bad ingredients as good; and secondly, to give a superior appearance to the loaf. Both objects are blameable, as far as they imply fraud, although there may be less of criminality involved in the latter than the former.

Alum and potato meal are the principal sophistications of the present day, but a desire of gain induces other adulterations consequent on these; namely, the retention of an excess of water, which weighs heavily without adding to the nutritive quality; and the means which the use of alum affords for incorporating bad or inferior articles.

Some bakers buy rock alum in powder, and mix it up in certain proportions with salt; the majority, however, make use of an article known in the trade as *hards* and *stuff*. This consists of a mixture of alum and salt. It is kept in bags holding from a quarter to one hundredweight, and is sold by the druggists, who supply either the baker or the corn chandler. In country towns and villages, the baker is put to considerable trouble to procure his *stuff;* for, as he is unwilling that his friends and neighbors should know that he makes use of any such article in his bread, he generally contrives to procure it from some druggist living some miles away from his own town. It is not easy to ascertain the proportion of alum and stuff used in the preparation of bread; it may, however, be stated as a general rule, that the worse the flour, the greater is the proportion of these ingredients used.—*Lancet.*

Various writers upon adulterations state the proportions of alum according to the facts which have come under their own notice. ACCUM gives an incontrovertible statement in reference to this; he says, upon the authority of his own baker:—The smallest quantity of alum that can be employed with effect, to produce a white, light, porous bread, from an *inferior* kind of flour, is from three to four ounces to a sack of flour, weighing two hundred and forty pounds. Others state the quantity to be eight ounces; and MITCHELL, from his own experiments, performed in each case upon a four-pound quartern loaf, tabulates the amount as follows:—

No.	1.	contained	116	grains	of alum.
"	2.	"	114	"	"
"	3.	"	109	"	"
"	4.	"	108	"	"
"	5.	"	105	"	"
"	6.	"	94	"	"
"	7.	"	58	"	"
"	8.	"	41	"	"
"	9.	"	40	"	"
"	10.	"	34½	"	"

making a total in ten loaves, or forty pounds of bread, of 819½ grains of alum.

It has been stated, that from ninety to ninety-two such loaves, or three hundred and sixty-two pounds of bread, can be made from a sack of flour of the above weight; according to the preceding, the average would be about sixteen and a half ounces of the alum, and if the first loaf be taken as the standard, the amount will be about twenty-four ounces per sack.

Alum acts chemically on the animal tissues and fluids. If a solution of it in water be added in certain proportions to albumen, it causes a white precipitate; it also forms insoluble combinations with milk and with gelatin. Hence the phenomenon of the action of alum on the fibrinous, albuminous, and gelatinous constituents of the living tissues, is easily explained and comprehended.

The immediate topical effect of a solution of alum is that of an astringent; namely, corrugation of fibres and contraction of small vessels, by virtue of which it checks or temporarily stops exhalation and secretion, and produces paleness of parts by diminishing the diameter of the small blood-vessels. It is by these local effects that alum, when taken internally, causes dryness of the mouth and throat, somewhat increases thirst, checks the secretions of the alimentary canal, and thereby diminishes the frequency, and increases the consistency of the stools, as observed by WIBMER in his experiments made upon himself with alum, in doses of three grains dissolved in five drachms of water, and taken several times during the day.

But when alum is applied to a part in large quantities, and for a longer period, the astriction is soon followed by irritation, and the paleness of preternatural redness. And thus taken internally in large doses, alum excites nausea, vomiting, griping, purging, and even inflammatory condition of the intestinal canal—effects which may be perhaps induced by small quantities in persons endowed with unusual or morbid sensibility of the stomach and bowels, as in the case of a lady in whom dangerous gastro-enteritis was apparently induced by a single dose, containing between ten and twenty grains of burnt alum.

After its absorption, alum appears to act as an astringent, or astringent tonic, on the system generally, and to produce more or less general astriction of the tissues and fibres, and a diminution of secretion.—*Lancet.*

Speaking of the effect of alum on the animal economy, DUMAS states:—Although it is not so dangerous as other adulterations practised by bakers, and its presence in the bread is not immediately productive of ill consequences, yet it is to be feared that this salt exerts a deadly action by its daily introduction into the stomach, especially in persons of a weak constitution.

Alum can be easily detected by taking a known weight of the bread, which is to be crumbled and macerated with cold water for a few hours; the extract is then removed by filtering through a clean linen cloth, and pressing out the whole of the solution. The residue is to be washed with a small quantity of distilled water, pressing out the whole of the solution each time. The washings and the first solution are passed through a paper filter, and then evaporated to dryness; the dry residue treated with water, filtered, and ammonia or chloride of ammonium added to the liquid, when a flocculent white precipitate of hydrate of alumina falls down. By collecting this precipitate, washing well with distilled water, drying, and heating to redness in a porcelain or platinum crucible, the quantity of the alumina is ascertained, and from this the corresponding weight of alum is found; for every fifty-two parts of alumina equal four hundred and seventy-five of alum.

KUHLMANN determines alum in bread as follows:—He incinerates two hundred grammes of bread, pulverizes the ashes, and treats them with nitric acid. He evaporates the mixture to dryness, pours about twenty grammes of distilled water on the produce of the evaporation, in the same manner as if he were testing for copper, then adds to the liquor, which it is not necessary to filter, caustic potassa in excess. After heating a little, he filters, and precipitates the alumina of the filtered solution by means of chloride of ammonium. The total separation of the alumina is only effected by boiling, to which it is proper to submit the liquid for some minutes. He then collects the alumina in a filter, and determines, from the weight of the alumina obtained, the quantity of alum in the bread.

It is to be remarked, that most bakers use alum in the manufacture of bread. Out of twenty-four samples of London bread examined by Dr. HASSALL, not one was found free from this pernicious ingredient; the Editor, from his numerous analyses of Liverpool bread, demonstrated the prevalence there of a similar practice, and the same may be said of all other towns. The fact has been alluded to, that flour which is made into bread with an admixture of alum, retains more water than genuine bread; and this is one end which the baker has in view in employing it, irrespective of the plausible excuse of making the bread white to please the public. If other ingredients, such as rice or potato flour, be used as a further adulterant with the alum, the quantity of water retained by it is still greater. As bread gets old, the water which it holds after baking dissipates more or less; the alum prevents this to a certain extent, but more particularly when the alum and rice, or potato flour, united, form the adulteration. This was proved in an experiment performed by HASSALL upon three loaves prepared expressly for the purpose; and composed respectively of—

	Flour.	Water and German yeast.	Alum.	Salt.	Rice flour.	Weight after taken from the oven.	Weight after twenty-four hours.
1.	2 lb.	sufficient quan.	sufficient quan.	sufficient quan.	sufficient quan.	2 lb. 8½ oz.	2 lb. 7 oz. 7 dr.
2.	2 lb.	"	40 grains.	½ oz.	½ oz.	2 lb. 10 oz.	2 lb. 9 oz. 3 dr. 1 scr.
3.	1½ lb.	"	40 "	½ oz.	½ lb.	2 lb. 10½ oz.	2 lb. 10 oz. 0 dr. 1 scr.

From this experiment, it will be seen that the first loaf lost five drachms, or more than half an ounce; the second, four drachms and two scruples; and the third, three drachms and two scruples; and that the bread prepared with genuine flour is less retentive of moisture than the adulterated article. The annexed table of HASSALL's shows the relative weight of bakers' bread, the loss it sustains by being kept, and its difference from the prescribed weight.

TABLE SHOWING THE WEIGHT OF BREAD AS DELIVERED AT HOUSES.

Loaves.			Weight.
FIRST BAKER.			
Quartern, new,		deficient	3¼ oz.
Ditto,	,,	,,	1¾
Ditto,	one day old,	,,	2½
Half-quartern, new,		,,	1½
Ditto,	stale,	,,	2½
Deficiency in four quarterns,			11½
SECOND BAKER.			
Half-quartern,	one day old,	deficient	1
Ditto,	,,	,,	1¾
Ditto,	,,	,,	1
Ditto,	,,	,,	2½
Deficiency in two quarterns,			6¼
THIRD BAKER.			
Half-quartern,	one day old,	deficient	2
Ditto,	,,	,,	2
Deficiency in one quartern,			4
FOURTH BAKER.			
Quartern, new,		deficient	2
Ditto,	stale,	,,	2½
Deficiency in two quarterns,			4½
FIFTH BAKER.			
Quartern, new,		no deficiency.	
Ditto,	stale,	deficient	2½
Deficiency in two quarterns,			2½
SIXTH BAKER.			
Half-quartern,	one day old,	deficient	1
Ditto,	,,	,,	2
Ditto,	,,	,,	0½
Deficiency in a quartern and a half,			3½
SEVENTH BAKER.			
Half-quartern,	one day old,	deficient	1 oz.
Ditto,	,,	exact weight	
Ditto,	,,	rather overweight	
Deficiency in a quartern and a half, less than			1
EIGHTH BAKER.			
Quartern,	one day old,	deficient	1½
Ditto,	,,	,,	1½
Ditto,	,,	,,	1
Ditto,	,,	,,	1½
Deficiency in four quarterns,			5½
NINTH BAKER.			
Half-quartern,	one day old,	deficient	2
Ditto,	,,	,,	2
Deficiency in one quartern,			4
TENTH BAKER.			
Quartern,	one day old,	deficient	3¾
Ditto,	,,	,,	3½
Ditto,	,,	,,	2¾
Ditto,	,,	,,	4
Half ditto,	,,	,,	2¼
Ditto,	,,	,,	2
Ditto,	,,	,,	2½
Deficiency in five and a half loaves,			1lb. 4¾
ELEVENTH BAKER.			
Half-quartern,	one day old,	deficient	1¾
Ditto,	,,	,,	1½
Ditto,	,,	,,	1½
Ditto,	,,	,,	2
Deficiency in four half-quarterns,			6¾
TWELFTH BAKER.			
Quartern,	one day old,	deficient	3
Ditto,	,,	,,	3½
Deficiency in two quarterns,			6½
THIRTEENTH BAKER.			
Half-quartern,	one day old,	deficient	0½
Ditto,	,,	,,	1½
Ditto,	,,	,,	1½
Ditto,	,,	,,	1½
Ditto,	,,	,,	2
Ditto,	,,	,,	1½
Deficiency in six half-quarterns,			8½

Sulphate of copper—blue vitriol—was at one time a favorite adulterant with many bakers, particularly those of the Continent. In reference to this substance, DUMAS writes as follows:—It is not known when the employment of the sulphate of copper in the manufacture of bread began, but it would appear to have been practised for a great number of years in Belgium, and even in the North of France. The advantages which the defrauders derive from it are numerous. They find it easy to use with it flours of a medium quality and mixed. The panification is more rapid, the soft part of the bread and crust have a finer appearance, and, lastly, they are enabled to use with it a greater quantity of water.

From accounts received by KUHLMANN, of the practice of some bakers, the quantity of sulphate of copper employed by them is very small. One put into the water intended for the preparation of a batch of two hundred loaves of one kilogramme—nearly two pounds and a quarter—each, a glass of liquor filled with a solution, containing one ounce of sulphate of copper to a litre—rather less than half a gallon—of water. Another employed only a pipe-headful of this solution.

If quantities of sulphate of copper, as trifling as those just mentioned, were uniformly diffused in the mass of bread, no immediate inconvenience would follow, perhaps, to a person in good health; but, in the long run, there must be injurious effects. Every one, in short, will conceive the danger of the fraudulent use of so poisonous an agent put into the hands of *a boy baker*, whose awkwardness or inexperience might be productive of very serious accidents. It is impossible, therefore, to adopt too rigorous measures against the introduction into bread of *the smallest quantities* of this poison.

And if it be imperative to punish severely offences of so grave a character, it cannot be of less importance to study with care the means which science may afford us for rendering their existence manifest.

Copper being one of those substances, the presence of which admits of the most accurate analytical demonstration, the examination of a loaf suspected to contain sulphate of copper seems at first to present no difficulty. Immediate contact with an ammoniacal solution, sulphide of hydrogen, or ferrocyanide of potassium, ought to remove all uncertainty. But if it be considered in how small a proportion this poisonous salt is commonly employed, it will be easily seen that these kinds of researches require longer analytical processes. Nevertheless, the action of the last-mentioned reagent becomes apparent, even when the bread contains only one part of sulphate of copper in about nine thousand parts of bread, by the almost immediate production of a rose color.

This process is useful only in some cases. To determine satisfactorily very minute quantities of the copper salt which might be contained in the bread, M. KUHLMANN had recourse to the following method, which he employed in the most delicate investigations, and which he put several times to the test, by introducing with his own hand into bread merely traces of sulphate of copper; one part in seventy thousand, for example, which represents one part of metallic copper to about three hundred thousand parts of bread.

In a platinum capsule, two hundred grammes of bread are completely incinerated. The produce of the incineration, after being thoroughly reduced to a very fine powder, is mixed in a porcelain capsule with eight or ten grains of nitric acid. This mixture is submitted to the action of heat till nearly the whole of the free acid is evaporated, and only a pitchy paste remains, which is mixed with about twenty grammes of distilled water, assisting its solution by heat. It is then filtered so as to separate the parts not attacked by the acid, and into the filtrate a small excess of liquid ammonia is poured, with some drops of solution of subcarbonate of ammonia. After cooling, the white precipitate formed in abundance is separated by percolation, and the alkaline liquor is submitted for some moments to ebullition, to dissipate the excess of ammonia, and reduce it to about a fourth of its volume. This liquor being rendered slightly acid by a drop of nitric acid, it is divided into two parts: the one part is submitted to the action of ferrocyanide of potassium, the other to sulphide of hydrogen, or sulphide of ammonium.

By carefully following this process, even if the bread should contain only *a seventy-thousandth part of sulphate of copper*, the presence of this poisonous salt will be rendered apparent; in the case of the first test, by the immediate pink or rose coloration of the liquid, and the formation, after resting some hours, of a light crimson precipitate. The action of the sulphide of hydrogen, or ammonium, would impart to the liquid a slightly fawn colour, with the formation, by resting a little, of a brown precipitate, less abundant, however, than the precipitate obtained by ferrocyanide of potassium.

DAVY, some time since, announced that carbonate of magnesia might be used by bakers with advantage, as it assists to keep the dough stiff, raise it, and neutralize any acidity which the flour may have contracted. The quantity required, according to this authority, depends upon the quality of the flour, beginning with twenty grains of the salt to a pound of flour. This compound, to produce the effects stated in the preceding, cannot but be prejudicial to health, to a certain extent; for the carbonate of magnesia will be converted during the fermentation of the dough into a soluble salt possessing marked purgative properties. It may be supposed that the substance in question, when used only in the proportions recommended by DAVY, is not injurious; still, however, its use enables the dishonest tradesman to practise a great fraud, by selling an inferior for a superior article, and should therefore be denounced.

The following is the method recommended by MITCHELL for its detection:—Ignite half a pound of the suspected bread in a crucible, till all blackness is removed; pulverize the remaining ash, add acetic acid, and evaporate nearly to dryness to expel the excess of it; act on the residue with alcohol, and filter; evaporate the filtered liquid to dryness and dissolve in water; then add an excess of ammonia and phosphate of soda, which throws down the magnesia as phosphate; collect this precipitate on a filter, wash, dry, ignite, and weigh; every hundred parts of the precipitate indicate about seventy-six parts of carbonate of magnesia.

Sesquicarbonate of ammonia, as before noticed, is used by the baker both to raise and whiten his product, and to enable him to work inferior flour, which may have become mouldy, into bread having all the appearance of the genuine article. As before stated, the whole of the ammonia is not expelled by the heat of the oven. This affords a means whereby ammonia is detected and the fraud exposed. The best way to proceed for its detection, is to mash half a pound of the bread in cold distilled water, and after half an hour strain off the liquid, add a few drops of hydrochloric acid, and evaporate to dryness in a water bath; the dry residue is next treated with a little strong caustic potassa; ammonia will by this means be disengaged, and may be known by its extremely pungent odor.

The other substances mentioned under the adulterations of flour, may be detected in bread as there directed; their use seems to be now entirely discontinued, as they effect no other ends apparently, than increasing the weight of the loaf. Should they be suspected to be present, simple incineration will prove it; good bread should leave about 0·75 to 1·00 per cent. of ash.

With regard to the use of adulterations in bread-making, DUMAS sums up as follows:—If the nature of the products employed, with the view of procuring a more advantageous result from flour of inferior quality, be considered, it is difficult to form an opinion on the part which these different substances perform in the fabrication of the bread. A great number of them seem rather calculated to retard the action of the fermentation than to promote it. What appears more especially incomprehensible, is the action that may be exercised on bread by quantities of sulphate of copper so very minute as those that have been used for this purpose.

With the view of throwing light on this question, KUHLMANN applied himself to numerous practical experiments, to elucidate the action of sulphate of copper, of alum, of carbonate of ammonia, of carbonate of magnesia, and some other salts.

The presence of the sulphate of copper employed in all these trials, displayed itself, even in the smallest proportion, in consolidating the dough, and preventing it from spreading or flattening.

The sulphate of copper exercises an action extremely energetic on the fermentation and raising of the bread: this appears in the most obvious manner, even when the cupreous salt is used in the proportion of only one grain of sulphate to seven and a half pounds of bread. The proportion which produces the greatest enlargement, or raising, is that of from one-thirty-thousandth to one-fifteen-thousandth part; but beyond this limit the bread becomes moist; it acquires a colorless white, and at the same time it possesses a particular odor, disagreeable, and having a resemblance to that of leaven.

Sulphate of copper having the property of *firming* the dough, it unfortunately happens that, by using it, a well-raised bread may be obtained with meal in that state said to be *slack*, or damp. The augmentation in the weight of the bread, in consequence of a greater quantity of moisture being retained in its composition, may rise to one-sixteenth, or one ounce per pound, without injuring the appearance of the bread.

It is especially in summer that the necessity of *firming* the dough, and preventing it from *running flat*, is felt. This is accomplished, in common practice, by the employment of leaven and marine salt. The action of a very small quantity of sulphate of copper corresponds, therefore, to that of these substances.

The largest quantity of sulphate that can be employed, without detracting from the beauty of the bread, is *one-four-thousandth* part; in a greater proportion, the bread is very watery, and presents large openings; and with one-eighteen-hundredth of the salt, the dough can by no means be *raised*, all fermentation seems arrested, and the bread acquires a greenish color. It must be observed, further, that a marked and disagreeable odor betrays itself in the bread as soon as the quantity of sulphate of copper introduced into it exceeds one part of that salt to seven thousand parts of bread.

Everything leads to the belief that, in the sulphate of copper, it is the base of the salt that exerts an influence on the panification, by giving a greater consistency to the affected gluten. Sulphate of soda, sulphate of iron, and even sulphuric acid itself, do not give, by comparative trials, any analogous result.

The effects produced by alum in the fabrication of bread, are nearly the same as those obtained with the sulphate of copper, but it is required to be used in much more considerable quantities. It has been seen that one-seventy-five-hundredth of sulphate of copper is much too large a proportion—so much so, indeed, that, instead of promoting, it retards the *raising* of the dough. The same amount of alum produces, on the contrary, no apparent result. To obtain a sensible effect, the quantity of alum must be raised to one-nine-hundred-and-thirty-sixth; in the ratio of one-one-hundred-and-seventy-sixth, the effect is more remarkable.

The action exerted by alum on the dough is absolutely the same as that of sulphate of copper; it *binds* it and makes it *swell out*, to use the terms applied by the bakers themselves.

The carbonate of magnesia does not produce a great effect on the raising of the bread; but, in the proportion of one-four-hundred-and-fortieth part, it imparts to the bread a yellowish color, which may advantageously modify the dull color given to bread by meal of inferior quality.

The carbonate of ammonia is not more marked in its results, and cannot be of great service for raising the bread, unless it is employed in a very large proportion.

Chloride of sodium possesses the property of *firming* the dough; it also increases the weight of the bread, and the addition of salt, instead of being an expense to the baker, is rather a profit or saving to the extent of the difference in the weight of the bread. A sufficient quantity of salt may admit of dispensing with the use of leaven; and the kneading alone, when continued a little longer than usual, permits of a considerable diminution in the quantity of ferment required.

While showing the remarkable results of the use of sulphate of copper in the making of bread, the researches of KUHLMANN prove, that by chemical analysis it is easy to detect in bread even the minutest proportions of this poisonous product. Each consumer can put in practice for himself a very simple test, which readily reveals the presence of sulphate of copper, even when this salt is not in quantity sufficient to occasion serious consequences.—*Dumas.*

It has lately been found that water saturated with lime, produces in bread the same whiteness, softness, and capacity of retaining moisture, as results from the use of alum; while the former removes all acidity from the dough, and supplies an ingredient needed in the structure of the bones, but which is deficient in the *cerealia.* The best proportion to use is, five pounds of water saturated with lime, to each nineteen pounds of flour. No change is required in the process of baking. The lime most effectually coagulates the gluten, and the bread weighs well; bakers must therefore approve of its introduction, which is *not injurious to the system* like alum, *et cetera.* A large quantity of this kind of bread is now made in Munich, and is highly esteemed.

After what has been said upon the adulterations practised in the making of bread, the reader may be curious to know whether anything has been done by our enlightened legislature to thwart this evil. The answer to this query is in the Act of Parliament, which is appended, *videlicet:*—

Bakers or sellers of bread are bound to have fixed, in some conspicuous part of their shop, a beam and scales, with proper weights for weighing bread; and a person purchasing bread may require it to be weighed in his presence. Bakers and others sending out bread in carts, are to supply them with beams, scales, *et cetera*, and to weigh the bread, if required, under a penalty of not more than £5.

Bakers, either journeymen or masters, using alum or any other unwholesome ingredients, and convicted on their own confession, or on the oath of one or more witnesses, to forfeit not exceeding £20, and not less than £5, if beyond the environs of London; and not exceeding £10, nor less than £5, if within London or its environs. Justices are allowed to publish the names of offenders. The adulteration of meal or flour is punishable by a like penalty. Loaves made of any other grain than wheat without the city and its liberties, or beyond ten miles of the Royal Exchange, to be marked with a large Roman M, and every loaf so exposed.

Any ingredient or mixture found within the house, mill, stall, shop, *et cetera*, of any miller, mealman, or baker, which, after due examination, shall be adjudged to have been placed there for the purpose of adulteration, shall be forfeited, and the person within whose premises it is found punished; if within the city of London and its environs, by a penalty not exceeding £10, nor less than 40s., for the first,—£5 for the second,—and £10 for every subsequent offence. And if without London and its environs, the party in whose house or premises ingredients for adulteration shall be found, shall forfeit for every such offence not less than £5, and not more than £20.

Such are the legislative regulations on the matter; but they are practically of no avail, and the admixture of alum with bread is general amongst bakers, just as if the law did not exist. It is said that the Act cannot be put in force, because its provisions are evaded by the bakers not keeping the adulterating substances on their premises, but sending them to the mill, there to be mixed with the flour. There is every reason to believe, however, that this is not the case, but that the introduction of alum into the flour actually takes place at the bakery. It is known for a fact, that many wholesale druggists keep for sale what is called *bakers' alum*, that is, pulverized alum, sophisticated with a certain quantity of common *salt*, and that it is sold to bakers, and delivered at their shops in that state. Admitting that the mixing of alum with the flour takes place at the mill, it does not appear that such an evasion of the law could at all shelter the delinquents; for if flour or the bread is found on the bakers' premises to contain alum, surely the drug might be legally considered as being there. It is true that the alum is then in a *mixed state*, but the law does not say anything regarding the state in which it may be; it declares only, that the *use of alum*, or *of any other unwholesome ingredient* in flour, is a punishable offence. At any rate, the practice of the miller clearly comes under the provisions of the Act, and it should, therefore, be enforced against him; but, says Dr. URE, who would choose to incur the trouble, responsibility, and expense of prosecuting a frequent misdemeanor of this kind? The answer might be:—A committee of competent gentlemen of acknowledged talent and probity, a Board of Health, as on the Continent.—*Normandy.*

BROMINE.—*Bromure*, French; *Brom*, German; *Brominium*, Latin.—This is an elementary body, discovered by BALARD, in 1826, in the mother-liquor of the salt-marshes of Montpellier. He called it *muride*, but, in consequence of its powerful odor, this term was exchanged for bromine—a derivative from a Greek word signifying a strong or rank smell. In its nature and relations it closely resembles chlorine and iodine; with one or other, and often with both, of which it is always associated. Although it is found in some minerals; in all sea waters, and springs which have been connected with the ocean; and in several mineral and salt springs in Germany, Switzerland, England, and America; and though even marine and some fresh water plants have been shown to contain it—still its relative quantity is very minute.

The source whence it is manufactured is *bittern*—the mother-liquor of sea-water, from which the chloride of sodium has been separated by crystallization—and its extraction from this liquid, though not a very complicated process, requires delicate attention. Its separation from the metals with which it may be in combination—sodium or magnesium—is dependent upon the greater affinity which chlorine has for these; and hence, when a current of this gas is transmitted through the solution, the bromine is liberated and a chloride of the metal is formed. That the bromine is disengaged, is known by the orange-yellow tint it communicates. Care must be taken that an excess of the chlorine is not used in liberating it, lest a portion might be expelled. If the liquor be now boiled in a close vessel, red vapors of bromine are evolved, and may be condensed into a liquid state in a receiver surrounded with ice. As there may be some chlorine in excess, the product obtained as above will not be pure; hence it is better to follow the course pursued by the discoverer for preparing pure bromine: by his method, when it is set free by means of the chlorine as already mentioned, the menstruum is agitated with ether; this liquor dissolves all the bromine, separating it from the bulk of the solution, and by decanting the ethereal extract, which appears of a fine hyacinth red color, and agitating it afterwards with aqua potassæ, bromide of potassium and bromate of potassa are formed, and may be obtained in a crystalline state by evaporating the liquid. When these crystals are dried, and distilled in a retort with an equivalent proportion of sulphuric acid and peroxide of manganese, the bromine is liberated, and by having the beak of the retort immersed in cold water it is collected as a blackish-red liquid. Another simpler and less costly process is followed in preparing large quantities of this element. It is as follows:—

Having deprived the mother liquor of sea water or brine, of as much of its salt as possible, by evaporation and crystallization, chlorine is developed in the liquor by acting upon binoxide of manganese with hydrochloric acid, or if sufficient salt still remains in the mother lie sulphuric acid might be substituted. The reaction in this case may be represented thus:—

$$\underbrace{Ca\,Br}_{\text{Bromide of calcium.}} + \underbrace{Mn\,O_2}_{\text{Binoxide of manganesium.}} + \underbrace{2\,H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{Mn\,Cl}_{\text{Chloride of manganesium.}} + \underbrace{Ca\,Cl}_{\text{Chloride of calcium.}} +$$

$$\underbrace{Br}_{\text{Bromine.}} + \underbrace{2\,H\,O}_{\text{Water.}}$$

KREUZNACH uses one ounce of the binoxide and five or six of commercial hydrochloric acid to about four quarts of the mother liquor, and distils the whole slowly by the heat of a sand-bath as long as vapors of bromine are evolved. By conducting the operation carefully, very little chlorine will be found in the recipient, for the mixture of manganese and hydrochloric acid is rendered too dilute by the lie to afford chlorine by their reaction, even when no bromine is present; hence the colorless vapors which are expelled at the termination of the distillation, are entirely composed of water and hydrochloric acid.

At the ordinary temperature, bromine is a liquid body, appearing, when in large quantities, of a blackish-red color; but when only a thin stratum of it is interposed between the light and the observer, a hyacinth-red. It is very volatile, giving off, when exposed to the air, reddish vapors similar to peroxide of nitrogen—NO_4. Between 2° and 13° Fahr., it congeals to a yellowish-brown, brittle, lamellar, crystalline mass. At 59° Fahr., its specific gravity is 2·98, and it enters into ebullition at 116·5°, giving off vapor having a density, according to MITSCHERLICH, of 5·54, and a hundred cubic inches of which at 60° weigh 167·25 grains.

Like the other elementary bodies, it is not altered by heat and light, and is a non-conductor of electricity. It is soluble in water, alcohol, and ether; it is a powerful bleaching element, destroying, like chlorine, the blue of indigo.

Organic matters are acted upon by it, and it is very destructive to animal life. It stains the skin yellow, but less intensely than iodine, and the color soon disappears.

It is very volatile; a drop put into a flask soon fills it with vapor, resembling that of fuming nitric acid, and a taper plunged into it burns for some moments, with a flame green at the base and red at the top, as with chlorine, and is then extinguished.

When metals come in contact with the fumes of bromine, combustion takes place, as with iron, arsenic, and antimony.

Bromine enters into several combinations with other elementary bodies; with five equivalents of oxygen it gives bromic acid—$Br\,O_5$—which unites with bases forming bromates; with hydrogen it affords bromide of hydrogen or hydrobromic acid—$H\,Br$—which has very powerful acid properties, analogous to those of hydrochloric; with metals it gives bromides, the most important of which are those of the alkalies and of silver, as they are highly useful in photography and its allied arts.

When the daguerreotype was first invented, the plate of silvered copper was rendered sensible to the rays of the sun by the vapor of iodine *per se;* but as the action in this case was very slow—often requiring half an hour—a combination of iodine and bromine was tried, and found to increase greatly the sensibility of the metallic plate, and to perfect the image almost instantaneously. In order to effect this object, the silvered mirror, previously acted upon by iodine, is exposed to the influence of a very weak solution of bromine water.

Its medicinal effects are various; in small doses, it acts as a tonic, diuretic, and resolvent. In all its therapeutic influences it is like iodine, but is said to be more energetic in its effects.

According to LÖWIG, it has very marked disinfectant properties.

The impurities which may be found in the bromine of the shops are water, chlorine, and iodine. If proper care has been exercised in its manufacture very little chlorine is present, but when the ethereal method of purification is resorted to, neither chlorine nor iodine can be detected in it. Any traces of water which it may retain are abstracted by distilling it over fused chloride of calcium, and condensing the vapor in receivers surrounded by freezing mixtures.

ANALYSIS.—Bromine and iodine are readily separated from each other by chloride of palladium, which precipitates the latter as an iodide of palladium, leaving the former dissolved. On filtering, evaporating the liquid to dryness, dissolving the residue, and mixing the solution with ammonio-chloride of silver, bromide of silver falls, which can be collected, dried, and weighed. Every 23·5 grammes of this salt will contain ten of bromine.

This method, proposed by LASSAIGNE, for the separation of iodine and bromine by a salt of palladium, is undoubtedly preferable to all others; but its extensive adoption is prevented by the great scarcity of the reagent.

When chlorine and bromine are together, they can be precipitated by nitrate of silver; the menstruum must then be heated, filtered, and the mixed silver salts dried, fused, and most accurately weighed; a portion of them is then taken, introduced into a tared bulbous tube,—the best way of effecting the transfer is to fuse the mass again,—and heated to liquefaction; the tube is then allowed to cool, and, when perfectly cold, weighed. A stream of pure chlorine gas, thoroughly desiccated by passing it through a tube filled with fragments of fused chloride of calcium, is now slowly transmitted through the mixed silver salts, and the contents of the bulb are reheated to fusion, agitating from time to time. After the lapse of about twenty minutes, the tube is removed from the chlorine apparatus, allowed to cool, held obliquely for some minutes, so as to replace the chlorine gas by atmospheric air, and finally weighed; the contents of the tube are again heated in a stream of the same gas for about ten minutes, and subsequently reweighed. If the results of the last two weighings agree, the process may be regarded as concluded; if not, the operation must be repeated. The amount of bromine originally present in the mixed precipitate of chloride and bromide of silver, is inferred from the diminution of weight which the tube exhibits at the end of the process. Let it be assumed that the mixture of chloride and bromide of silver weighs twenty grammes, and that the decrease of weight consequent upon the transmission of the chlorine amounted to one gramme,—How much bromine then did the mixture contain?

Here it need simply be borne in mind, that the decrease of weight is the difference between the weight of the bromide of silver originally present, and that of the chloride which has replaced it. The difference between the respective equivalents of bromide and chloride of silver is to the equivalent of the former, as the ascertained decrease of weight is to the bromide of silver originally in the mixture; or, expressed in numbers:—

As 44·5 : 188· :: 1 : 4·224.

The twenty grammes of the analysed mixture contained accordingly 4·224 grammes of bromide of silver, and the amount of bromine bears the same relation to the quantity of bromide obtained, as the atomic weight of bromine does to that of its silver salt; thus—

As 188 : 80 :: 4·224 : 1·797.

The results obtained in this way are *extremely accurate;* but if only an approximation to the truth be required, the solution under examination may be precipitated with nitrate of silver; the precipitate collected, washed, dried, heated to a state of semi-fusion, and subsequently reduced by means of zinc, in conjunction with a little dilute sulphuric acid; the acid solution of chloride and bromide of zinc thus produced, is precipitated with baryta water in excess, and the fluid filtered off from the mixed precipitate of hydrated oxide of zinc and sulphate of baryta, which is then thoroughly washed upon the filter. The filtrate is evaporated to dryness, and the residue treated with absolute alcohol, which dissolves the bromide of barium, leaving the chloride intact.

By evaporating the alcoholic solution, and weighing the bromide, the quantity of its bromine is easily ascertained: thus, if two grammes of bromide had been obtained, then, as the atomic weight of one equivalent of bromide of barium is to that of one of bromine, so is the weight of the resulting bromide to the quantity of bromine; or, in figures:—

As 148·5 : 80 :: 2 : 1·079 grammes,—

the bromine contained in two grammes of bromide of barium; the per centage may be calculated thus:—

As 2 : 1·079 :: 100 : 53·95 per cent.

When bromine only is present, its quantity is readily determined by adding nitrate of silver in excess, heating, filtering, drying, and weighing the precipitate, each gramme of which contains ·4255 of a gramme of bromine.

BUTTER.—*Beurre*, French; *Butter*, German; *Butyrum*, Latin.—Butter, in the chemistry of former days, was a name for various metallic salts, especially chlorides; as butter of antimony—sesquichloride of antimony; butters of arsenic, bismuth, tin, and zinc, which were the sublimed chlorides of those metals. These terms, however, are well nigh exploded, and the synonym at the present day is generally understood to refer to the fatty matter obtained by the aggregation of the lighter particles of milk, and more especially that of the cow. Butter is also obtained from vegetals. The inhabitants of Kebba collect the fruit of the *shea-tree*, and from it prepare *vegetal butter*. This tree grows naturally and very abundantly in the woods. It resembles, in appearance, the American oak, and the fruit is like the Spanish olive. The kernel is enveloped in a sweet pulp under the rind, and the butter produced from it, besides possessing the advantage of keeping for a full year without the addition of salt, is white, fine, and sweeter than the best that can be procured from the milk of the cow.

A dissertation on butter may be thought by some, perhaps, to be out of place in a work of this kind. If nothing should be noticed by the chemist but such articles as require chemical processes or manipulation, the opinion would undoubtedly be correct: there is no material, however, on which the every-day observer can lay his hands or exercise his reasoning powers, but furnishes labor, more or less interesting, to the analyst. Amongst these objects, milk, and its most valuable ingredient butter, hold no mean position. The changes which are continually occurring in the former—the alteration it undergoes on exposure to the atmosphere, from the slightly alkaline to the acerb state, with separation of cream, and numerous others, afford most interesting subjects for investigation and research.

As butter is an article which cannot be treated of satisfactorily without a notice of milk, a few remarks will be made on the latter, prior to entering upon a description of the processes necessary for the making of butter.

MILK—*Lait*, French; *Milche*, German; *Lac*, Latin—is an opaque, whitish fluid, secreted by the mammary glands of the females of animals belonging to the class *Mammalia*, evidently intended for the nourishment of their young. It has an agreeable, sweetish taste, and a slight but pleasant odor, which becomes more perceptible when the milk is warmed. The milk of the cow is rather heavier than water, having a specific gravity of about 1·030. It consists of three component parts: the *butyraceous*, or oily substance of which butter is composed; *caseous* matter, from which cheese is formed; and the *serum*, or whey. These three ingredients differ materially in specific gravity, and to separate them is the chief object of the dairy. The curd is the heaviest, and the cream the lightest. Cream is a term now exclusively applied to the oleaginous yellowish-white stratum which collects upon milk that has stood for some hours. The chief constituent of cream is butter, but as there is always more or less of milk mixed with it, a particular action is requisite for its separation. This is performed by agitation, as fully explained at page 398. Milk has been repeatedly analysed; the following may be taken as its average composition:—

	Centesimally represented.		
	Way.	Boussingault.	Editor.
Casein,..........	4·48	3·20	3·74
Butter,..........	3·13	4·10	4·43
Milk-sugar,......	4·77	5·10	4·83
Water,..........	87·02	87·40	86·43
Saline matter,....	0·60	0·20	0·57
	100·00	100·00	100·00

The richness of milk is derived from the butter, the sweetness from its sugar, its consistency from the casein, its refreshing quality as a beverage from the water, and its peculiar flavor from its saline constituents.

From some experiments on the chemical composition of milk, Dumas has found that the milk of herbivorous animals always contains the four classes of matter which form the chief part of their sustenance, namely: the albuminous portion of the food, represented by casein; the fatty matters, by butter; the amylaceous ingredients, substituted by sugar of milk; and lastly, salts of different kinds. In the milk of carnivorous animals, on the other hand, one of these principles—the sugar of milk—is completely absent, unless bread or other substances containing saccharine, or amylaceous ingredients, has formed part of their food; the albuminous, fatty, and saline principles are found in abundance. As a proof that the existence of sugar in the milk of carnivorous animals is dependent on their having partaken of food containing starch, it is sufficient to confine them entirely to animal diet, when no trace of saccharine matter will be detected in their milk; then, to mix bread, or other amylaceous substance, with their food, upon which the presence of the sugar will become quite perceptible. Although the above evidence is strong, yet Dumas is of opinion, that more is requisite before it can be concluded that the formation of milk-sugar is absolutely impossible unless starchy matters have constituted a part of the food. It was ascertained, moreover, that by altering the proportions of the different elements of food, the relative quantities in which these elements appeared in the milk also varied.

When Dr. Wilson found, in 1846, that fluor spar was soluble in water, and that it existed in many natural waters, it occurred to him that it might possibly be contained in blood, and also in milk. He accordingly performed a series of experiments which gave affirmative results. Nine imperial pints of rich milk from a country farm were operated upon in the usual way—namely, by treating the residue with concentrated sulphuric acid, and allowing the vapors to come in contact with a polished surface of glass—and the evolved vapor distinctly etched glass. Fluorine was detected in a similar manner in the ashes of twelve pounds of new skim-milk cheese, and of four pints of whey. Dr. Wilson presumes that this element is present in the state of fluoride of calcium, and thinks that this salt is associated with the phosphate of lime, and separates, when milk is coagulated, along with the casein.

Newly-drawn milk is almost always slightly alkaline: this character, however, it speedily loses on exposure to the air; hence, when quite fresh, it often reddens litmus paper. It has been stated by some persons, that if left too long in the udder it sours—? A little acetic or dilute hydrochloric acid, added to milk warmed to 100° Fahr., causes it to coagulate and separate into two portions, the curd and whey: rennet, or sour milk, produces the same effect. Milk boils and freezes at about the same temperature as water. At a depressed temperature, it will remain sweet for several days; at 60° it acidifies rapidly, and at 70° or 80° still more speedily. Sour milk warmed, undergoes fermentation, and when distilled yields alcohol, as shown at page 116.

The quality of the milk is greatly influenced by the quantity of the yield, and the nature of the food given to the animal. The amount depends very much on the method of milking, as a cow roughly handled will withhold a portion of her milk, when, were she gently treated, she would allow it to be taken freely. It is of some importance that the last drop should be withdrawn, for although the statement that the last half pint is richer in cream than the whole milking besides, is not *fully* to be credited, yet, to a certain extent, it is true; besides, were any milk left, it might coagulate, and injure the udder, as well as lessen the subsequent *meals* of milk.

The influence of the food given to the cows in the stall, or eaten in the field, upon the color and flavor of the butter, is familiar to all practical men. The taste of the turnip in winter, that of garlic in summer where the wild onion grows in the pastures, and the effect of raw potatoes in giving a rich color, are common examples. The Editor finds that the richest and best tasted milk in winter, is that from cows fed upon mangel-wurzel and oil-cake.

The sour taste in milk is owing to the formation of *lactic acid*, first discovered in it by Scheele. This acid is also generated during the fermentation of the juices of the beet, turnip, and other bulbous roots. The casein in the milk gradually converts milk-sugar and other kinds into this acid: if a small portion of casein be introduced into a solution of cane or milk-sugar, lactic acid soon forms. But when this metamorphosis has occurred, the transforming action of casein does not cease: in time, according to Pelouze and Gelis, a fermentation commences, during which carbonic acid and hydrogen are eliminated, and *butyric acid* is produced—two equivalents of lactic acid giving one of butyric acid, four of carbonic acid, and four of hydrogen, thus:—

$$\underbrace{2\,(C_6\,H_6\,O_6)}_{\text{Lactic acid.}} = \underbrace{H\,O, C_8\,H_7\,O_3}_{\text{Butyric acid.}} + \underbrace{4\,C\,O_2}_{\text{Carbonic acid.}} + \underbrace{4\,H}_{\text{Hydrogen.}}$$

Every chemist is aware that, in these decompositions, it is seldom that one compound is obtained, for though the above equation truly shows how butyric acid and other products may result from lactic acid, yet other acids—capric, caprylic, caproic—are not unfrequently formed during the experiment, by which more or less complication ensues.

Butyric acid thus produced emits a mingled odor of acetic acid and *rancid butter;* hence the spoiling of this important dairy product is partly to be ascribed to the generation and presence of this acid in the milk.

As a general rule, it may be stated that the more casein that is left in butter, the greater is its tendency to rancidity. To render this plain, attention must be bestowed upon the normal ingredients of pure butter. Margarin and olein consist of margaric and oleic acids, united with an organic base, designated oxide of *lipyl.* Oleic acid absorbs oxygen from the air with great rapidity, producing peculiar compounds, and by this means acquires a very strong smell,—another of the causes of rancescence. The main source, however, is, as before stated, the formation of butyric acid: capric, caproic, and capryllic acids are also formed by the casein acting on the sugar; the first has a smell similar to that of a goat, hence its name; the second that of perspiration; while capryllic acid is the only one not obnoxious to the olfactory nerves.

One of the best methods for the complete analysis of milk is as follows:—Weigh out a portion of the milk to be operated upon, add to it a few drops of acetic acid, which will cause coagulation, and evaporate the whole to dryness in the water-bath. If the residue with the vessel containing it be now weighed, and the amount deducted from that of the vessel and milk, the difference will be the water. The solid mass must now be digested for some time with ether, then carefully placed upon a tared filter, and thoroughly edulcorated with this menstruum heated to its boiling point. The mixture of milk-sugar and casein remaining on the paper should then be dried at 212°, and weighed; the loss will represent the butter abstracted. The ethereal solution itself may now be evaporated at the same temperature in a tared vessel; the result will be the butter with a little coloring matter, more or less intense, according to the character of the food. The amount of this, when weighed, will verify the loss found by treatment with ether. This last process, however, is not *essentially* necessary.

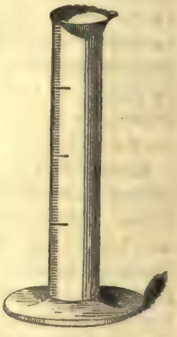
If now the casein and sugar be washed with *hot* water, the latter, with some of the inorganic salts, will be taken up by this menstruum; the solution is next evaporated at 212°, the residue weighed, then carefully incinerated, the amount of ash noted, and the quantity of sugar determined by subtracting the weight of the ash from that of the residue before obtained. The casein, *et cetera,* remaining on the filter, after drying in the water-bath, is weighed, then incinerated, the ash determined and deducted from the former residue; the difference is the casein. The total amount of ash in the milk may be ascertained by adding the weight of the soluble to that of the insoluble salts.

HAIDLEN has devised another system for the analysis of milk, the principal feature of which is its evaporation with sulphate of lime—gypsum. It differs little in any other respect from that above given, except that the milk-sugar and soluble salts are dissolved out by alcohol. For a complete determination of the constituents of the milk, this method has few, if any, advantages, but when it is merely required to ascertain the per centage of butter, it affords a ready means of coagulation. For this purpose a portion of milk is weighed, about one-fourth or one-fifth its bulk of gypsum added, and thoroughly incorporated. The whole is next carefully evaporated to dryness at 212° Fahr., the mass detached and pulverized in a warm agate or porcelain mortar, and digested with ether; the solution is filtered, the residue *well* edulcorated with the same solvent in a state of ebullition, and then the solution and washings evaporated in the water-bath, and the residue—butter—weighed; the numbers obtained represent the quantity of butter, from which the per centage may be readily calculated. Thus, for example, if 9·78 grammes of milk were taken, mixed with gypsum, evaporated to dryness, and the ground residue treated with ether, and if the weight of butter obtained on evaporation was ·402 gramme, then

As 9·78 : ·402 :: 100 : 4·11 per cent.

A simple method of ascertaining the quality of milk has been based upon the fact that cream, after several hours' standing, separates completely from milk. It is effected by means of an instrument termed a *lactometer,* represented in Fig. 246, and which is simply a tube about five inches long, divided into one hundred parts; of these, however, it is only necessary that twenty-five should be marked. The milk to be examined is poured into the tube up to 0, and the whole is left in a clean and moderately cool place for ten or twelve hours in summer, and from fifteen to eighteen in winter. At the end of this time, the whole of the cream will have risen up, and its per centage is then seen by the number of degrees it occupies. The thickness of the stratum of cream in pure milk is generally about eight per cent. If the milk submitted to examination has been mixed, say with one-third of water, the quantity of cream produced will be reduced to six and a half; if diluted with one-half its volume of water, the cream will be only about five and a quarter per cent., and so on in proportion.

Fig. 246.



The lactometer may evidently prove useful to the consumer, but more especially to the farmer, who may, by its aid, ascertain pretty accurately the relative influence of various kinds of food in giving richness to the milk.

Milk as a Manufacturing Ingredient.—Milk now performs other offices besides the production of butter and cheese, and the flavoring of tea. It has made its way into the textile factories, and has become a valuable adjunct in the hands of the calico-printer and the woollen manufacturer In the class of pigment-printing work, which is indeed a species of painting, the colors are laid on the face of the goods in an insoluble condition, so as to give a full, brilliant appearance. As a vehicle for effecting this process of decoration, the insoluble albumen obtained from eggs was always used, until Mr. PATTISON, of Glasgow, found a more economical substitute in milk. For this purpose, buttermilk is now bought up, in large quantities, from the farmers; and the required insoluble matter is obtained from it at a price far below that of the egg albumen. This matter the patentee has called *lactarin.* A second application of the same article, milk, has just been developed, by causes arising out of the recent high price of olive oil, which having risen from forty to seventy pounds a ton, the woollen manufacturers are now using the high-priced article mixed with milk. This compound is said to answer much better than oil alone, the animal fat contained in the globules of the milk apparently furnishing an element of more powerful effect upon the fibres, than the pure vegetal oil *per se.*

HISTORICAL SKETCH OF BUTTER.—Though butter may be considered as one of the most common of all ordinary things, yet the ancients were nearly, if not entirely, ignorant of its existence. The older translators of Hebrew seemed to think that they had met with it in Scripture, but most modern biblical critics agree that what was formerly interpreted butter, signified milk or cream, or, more properly, sour thick milk. The word referred to plainly alludes to a liquid, as it appears that the substance meant was used for washing the feet, and that it was imbibed, and had an intoxicating influence. It is well known that mares' milk, when sour, has a similar effect. Those acquainted with the authorised version of the Bible, would infer, on reading the thirtieth chapter of Proverbs, that butter was prepared by shaking or beating; the original, however, signifies pressing or squeezing, evidently meaning milking, and not the making of butter.

HERODOTUS, in his account of the Scythians, makes obscure mention of butter; this is the oldest reference known. HIPPOCRATES, who was almost contemporary with him, speaks more clearly on the subject, and also alludes to cheese. The poet ANAXANDRIDES, who lived a short time after HIPPOCRATES, in describing the marriage of IPHICRATES, and the entertainment then given, says that the Thracians ate butter, which the Greeks, at that time, considered as a wonderful kind of food. The word *butter* does not occur in ARISTOTLE, and he even scarcely alludes to it, though he gives very correct information respecting milk and cheese, which seems to imply careful observation. In STRABO, three passages refer to the subject, but little information can be elicited from them. PLUTARCH relates that a Spartan lady paid a visit to BERENICE, the wife of DEJOTARUS, and that the former smelled so much of sweet ointment and the latter of butter, that neither of them could endure the other. ŒLIAN states, that the Indians anointed the wounds of their elephants with butter.

DIOSCORIDES and GALEN give more important information. The former says that butter was prepared from the fattest milk, such as that of sheep, by agitating it in a vessel till the butter separated. To this butter he ascribes the same effects, when employed externally, as those produced by it at the present day. It appears he was the first writer who observed that butter might be poured, in a melted state, over pulse and vegetals, instead of oil, and that it could be used in pastry. A kind of soot was at that time prepared from butter, which was applied externally in inflammation of the eyes and other afflictions. For this purpose the butter was burnt in a lamp, which was constantly re-filled, until a sufficient quantity of carbon had been deposited in the vessel placed over it.

GALEN remarks that the secretion of the cow produces the best butter; that made from the goats' being less rich, and asses' milk giving the poorest. He expresses his astonishment that DIOSCORIDES should say that butter was made from the milk of sheep and goats. Butter, says he, may be very properly employed for ointments, and when leather is besmeared with it, the same purpose is answered as when it is rubbed over with oil. At the end of the second century. butter appears to have been very little known to, or used by, the Greeks or Romans. The Roman writers who give an account of the ancient Germans, relate that they lived chiefly upon milk; in one point, however, they disagree, some of them saying that they used cheese, while others affirm that they were not even acquainted with the method of preparing it. PLINY affirms that they did not make cheese, but butter, which they used as a most pleasant kind of food.

From the various statements in history, it may be safely concluded that the discovery of butter is attributable neither to the Greeks nor Romans, but that the former were made acquainted with it by the Scythians, Thracians, and Phrygians, and the latter by the people of Germany. It appears, says BECKMANN, that when they had learned the art of making it, they employed it only as an ointment in their baths, and particularly as a medicine. It is never mentioned by GALEN and others as food, though they have spoken of it as applicable to other purposes. No notice is taken of it by APICIUS, nor is there anything said in that respect by the authors who treat on agriculture, though they have given accurate information regarding milk, cheese, and oil. This may be easily accounted for by the fact, that the ancients were entirely accustomed to the use of good oil. In like manner, butter is very little employed at the present day in Italy, Spain, Portugal, and the Southern parts of France, but is sold in the apothecaries' shops for medicinal purposes.

During the ages of paganism, butter appears to have been very scarce in Norway: mention is made by historians of a present of butter so large that a man could not carry it, and which was considered as a very respectable gift.

PREPARATION OF BUTTER.—Before describing the routine of operation in the making of butter, it will be necessary to notice briefly the construction of the principal utensil required, namely:—

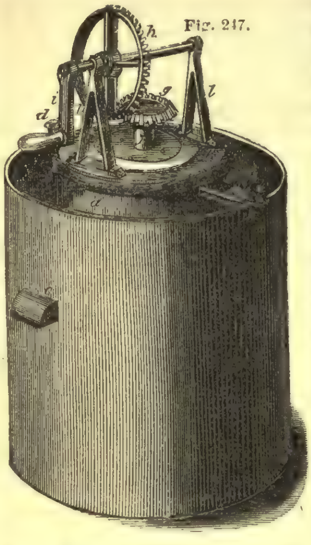
The Churn.—The various forms of churns may be arranged into four divisions:—Firstly, Those in which the fluid, the vessel containing it, and also the agitators, are in rotary motion. Secondly, Those in which the receptacle for the fluid is at rest, and the agitators in rotative movement *horizontally.* Thirdly, Those in which the containing vessel is fixed, and the agitators are in a state of *vertical* rotative motion. Fourthly, Those wherein the vessel is at rest, and the agitator has a *rectilineal* vertical motion.

It would be needless to describe particular specimens of each variety; and therefore such only as are in most common use will be adverted to.

The old-fashioned upright plunge churn—an example of the last of the above-mentioned classes—is now, when worked by the hand, chiefly confined to the use of small farmers; it is employed, however, when moved by mechanical power, in many very extensive establishments.

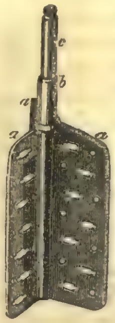
The barrel churn—belonging to the first variety—so much in vogue upwards of twenty years ago, is now disused. It has been superseded by the box churn—of the third class—the agitators of which generally move vertically; it is seldom seen with these in a horizontal position, except in town dairies, where it is worked by machinery.

Fig. 247.



In the same class stands the table churn, which is remarkable for its elegance and cleanliness, and is well adapted for the lighter purposes of the dairy. This apparatus is represented in Fig. 247 with an outer case, *c*, to contain hot or cold water. Its chief part is the receptacle, *a*, made of the finest and strongest white glazed Wedgwood ware, and having a capacity of from one to four gallons; it is furnished with a varnished wooden cover, *b*. The outer case is two inches wider than the churn, and is provided with handles, *c*, and two ears, to which the iron cross bar, *a'*, is attached by two thumb-screws, *d*, *e*, serving to secure the cover to the top of the vessel. An iron spindle, armed with three vanes, is fitted to turn in the brass socket, *f*, which is fixed in the cover: a wooden pulley is usually placed in the position of the wheel, *g*, on the top of the spindle, and, when secured there, it holds the latter and cover in constant connection. The usual medium of power is the common drill-bow, the string of which being held in tension by the elasticity of the steel back or bow, any movement of the instrument backward or forward causes the pulley and spindle to revolve. When the cover and spindle have been secured by the screws, *d*, *e*, and the bow-string applied by bending the bow until the string is sufficiently relaxed to allow of its being laid once round the pulley, the bow is then permitted to expand, and motion being communicated, the operation proceeds. The drill-bow is admirably adapted for reversing the motion of the pulley, for in pushing the bow forward by the hand, the agitator is made to revolve two or three times, the number being in proportion to the length of the string to the circumference of the pulley, and in drawing it back the same number of revolutions will be made in the opposite direction, and so on till the process is completed. Fig. 248 is a view of the agitator: *a a a* are the perforated vanes, made of strong tin plate; *b* is the part of the spindle that turns within the socket, and *c* that on which the pulley is fastened.

Fig. 248.



The drill-bow being, in unmechanical hands, a rather awkward medium of power, the common winch-handle is sometimes substituted, as shown in Fig. 247, where *h* is a tooth-bevelled wheel, on the axle of which the handle, *i*, is fixed; it gears with the wheel, *g*, fixed on the top of the agitator spindle, *f*, in the place occupied by the pulley when the drill-bow is the motive power. The axle of the wheel, *h*, is supported by two standards, *l l*, fixed on the cover, *b*. By this arrangement, two turns of the handle produce the same result on the agitator as is generally effected by one stroke of the bow: the motion being reversed at each second revolution, the result is the same as before, and the manual operation is, in this case, more easy. On being used, all the parts of the churn should be taken asunder and cleansed.

Fig. 249 represents a common box hand-churn. Its inside dimensions are—length eighteen, width eleven, and depth twenty inches. It is best made from birch or plane-tree, and requires to be very carefully joined, so as to be water-tight. It matters little whether the bottom is formed to the circle of the agitator or not, so far as the production of butter is concerned, but, for facility of cleansing, the curved form is far preferable. A cover of the same kind of wood as the churn is fitted closely into the top of the box, and provided with convenient handles. The agitator—Fig. 250—is of the usual shape. The dimensions of its parts are unimportant, provided they have sufficient strength, and present an extent of surface large enough to produce the required degree of agitation in the fluid.

Fig. 249.

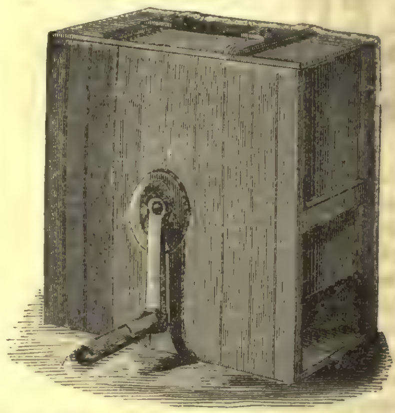
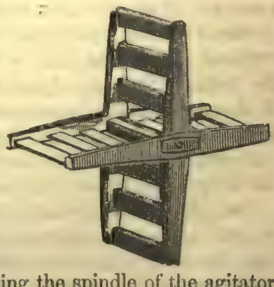


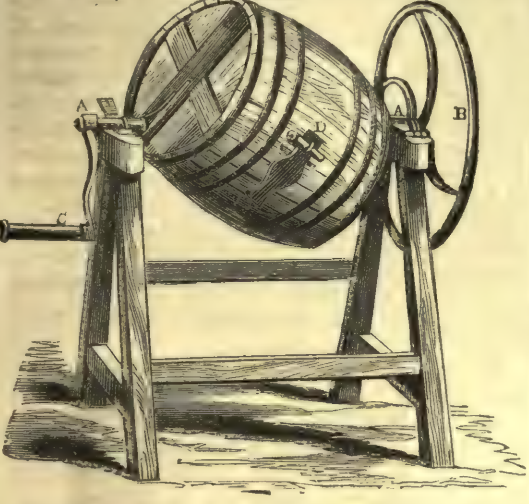
Fig. 250.



Various methods of securing the spindle of the agitator have been tried; the main object to be attended to is the prevention of leakage at the bush.

Mr. L. **TINDALL**, of Scarborough, has recently taken out a patent for a very efficient machine, which he has termed the diagonal churn, represented in Fig. 251. Hitherto revolving churns have been mounted to turn on spindles, coinciding with the axis or centre line of the barrel, but in this case the axis of revolution is at an angle with that of the vessel. The churn is supported upon an open wooden frame, on the top of which are bearings, A A, to receive two short spindles, set in the same axial line, and attached at opposite edges of the ends of the barrel; at one end is a small fly-wheel, B, for steadying the action, and at the other the driving winch, C, is fitted. The bung-hole, or charging aperture, is represented at D. In this churn the liquid partakes of a species of duplex or differential movement; for, as the barrel rotates, the cream always tends to descend to the lowest part: this causes it to traverse from end to end, each extremity being raised and lowered during a revolution; and as this is combined with the simple rotation, the cream is necessarily turned over in all directions, producing an admirable result. Its operation is very easy, and a much shorter time is required in churning—two points which render it superior to several kinds already in use. Like all other churns, it ought to be scalded previous to being put in operation: the cover is then removed, and the cream introduced till it is about three-quarters full. The patentee recommends 60° Fahr. as the proper temperature. The cover is now wrapped over with a piece of coarse cloth to render the whole perfectly tight, and replaced, and a rather slow motion communicated until the butter is formed. A wooden tap is fixed near one of the extremities, diametrically opposite to the bung-hole, which is occasionally opened to let out the air.

Fig. 251.



A double churn, represented in Figs. 252 and 253, has lately been patented in France by M. RENNES.

The principal improvement consists in the mechanism for moving the piston-rods, T T. It will be observed, from the figures, that this mechanism is composed of a grooved pulley, A, which turns freely round a fixed axis, and receives on its outer circumference the cords, *c c*, which are fastened at one end to points in the periphery of the pulley, and secured by their other extremity to the vertical rods, T, terminating in the pistons, P. In one piece with the disc, A, or in rigid connection with it, is an iron gudgeon, to which is attached the flat connecting-rod, E, keyed at its extremity to the fly-wheel, G, by the bolt, F. This bolt is prolonged outwards to form a handle or winch, by means of which the fly-wheel is turned, and thus the connecting-rod put in motion. As the distance from the centre of the pulley to the gudgeon is greater than the radius of the winch-handle, it is evident that, although the bolt, F, describe an entire revolution in the movement of rotation impressed upon it, the gudgeon will simply describe an arc of a circle, the range or chord of which will be equal to double the radius of the handle; and since the gudgeon is solid with the pulley, A, the latter will only receive an alternating circular movement. In this movement, the points of attachment of the cords, *c*, necessarily also describe similar arcs, and consequently force the rods, T, with which they are likewise connected, to rise and descend alternately. As these rods pass through the upper cross-piece which forms the cover of the box, J, they, as well as their pistons, work in a straight line; and being diametrically opposite, in reference to the centre of the pulley, it follows that the one descends while the other rises, and *vice versâ*

In applying this ingenious method of converting a circular into a rectilinear movement, to an apparatus for making butter, the inventor was led to modify and improve his apparatus in other respects. Thus the box, J, containing the cream, is so contrived as to allow the ingredients to be put in or taken out with great facility. At the top, on one side, is a lid, K, either attached by a hinge, or simply fitted on the box, to be removed when necessary. In like manner, at the lower part is an opening for allowing the escape of the buttermilk after the operation is finished, which opening, when the apparatus is in operation, is closed by the valve, M. A vertical partition, N, pierced with holes, separates the churn into two compartments, in each of which a piston, P, works. When necessary, the box or churn, J, may be placed in a tub or other vessel, O, of wood or of metal, which may be filled with warm water in winter, to accelerate the operation.

Fig. 252.

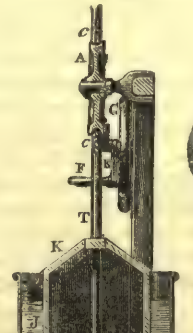
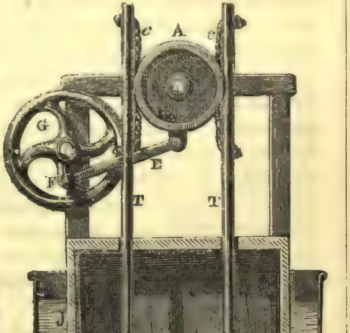


Fig. 253.



Thus the improvements introduced by M. RENNES into apparatus for making butter, comprise not only the particular arrangement of the mechanism for moving the pistons, but likewise modifications in the construction of the box or churn, properly so called; and, in particular, the addition of lids and valves to facilitate the admission and withdrawal of the materials, without requiring to take the whole to pieces.

PROCESS OF CHURNING.—The theory of this operation is very simple; by agitation, the envelopes of the globules of butter are broken, and on coming into contact they mutually adhere, and form a mass more or less solid.

The introduction of air during churning, aided by the temperature of the milk or cream, tends to change the sugar of milk into lactic acid, which coagulates the casein, and very materially assists the separation of the butter: the constituents are thus entirely re-arranged.

In converting cream into butter, the primary act is to put the churn into a proper state: though well cleaned after being formerly used, it should be again scalded with hot water. After this—in summer, but not in winter—it should be rinsed with cold water.

Some people add a little salt to the cream before agitating it, and it is stated to have a beneficial effect. Can this be owing to the chloride of sodium, influencing the coagulation of the caseous matter? The cream is strained into the churn through a bag of coarse linen cloth, which should always be washed without soap, and kept sweet by exposure to the air: it is dipped in water and then held over the churn, and on the cream being poured into it from the jar, the liquid and semifluid portions will, on the application of a gentle pressure, percolate, leaving a clotted residue containing many impurities, which it is impossible to keep out of a cream jar that is daily opened.

The excellence of butter is greatly influenced by the temperature of the milk or cream at the time of churning; if the latter is either too hot or too cold, the butter accumulates with difficulty, and when obtained is usually of inferior quality. With regard to this point, many experiments have been performed, and the result has fixed the most suitable temperature of the cream in commencing the churning, at from 50° to 55° Fahr. If the whole milk is operated upon, it should be about 55°. Thus, in summer, cream would require cooling, and in winter, the application of a little warmth. The time at which the butter separates, as also the quantity obtained, are greatly influenced by the temperature. The advantages of churns which have outer cases for the application of cold or hot water, as also the important benefits to be derived from the use of the thermometer in the dairy, are, therefore, obvious.

The agitation should, at first, be slow, until the cream has been completely broken—that is, rendered a uniform mass—when it becomes thinner, and the operation is found to be more easily performed. During the breaking, a good deal of gas is evolved, which escapes from under the cover. The motion may, after this, be slightly increased and continued, till a change in the sound, from a low and smooth, to a harsh tone, is observed, and an unequal resistance is felt to be given to the agitators. The butter may now be expected soon to form; by again slightly accelerating the motion, its aggregation will be more quickly effected, and the moment it becomes firm and the agitators are impeded, the process should stop.

The rate of motion in churning is of some importance, for when too slow, not only is a longer time spent than is necessary, but the butter acquires an unpalatable flavor; if, on the contrary, the movement is too rapid, it will be soft and frothy, and is said to have *burst*. In very hot weather, or when the cream is churned at too elevated a temperature, bursting is liable to take place with any considerable degree of motion, and then the exercise of judgment is specially required in its regulation. When butter, from cream, forms in forty-five minutes or an hour, the result is sure to be satisfactory, when it appears sooner it is soft, and if later is strong tasted.

It has been stated, in advertisements of table-churns, that butter may be obtained in them in twelve minutes. Parties known to the Editor have made experiments with such table-churns, in churning cream at different temperatures and speeds, but *good* butter was never obtained in less than twenty minutes, and even then it was soft and frothy.

The temperature rises 3° or 4° during the agitation required.

The utensils required for the making of butter are:—A small tub for holding it immediately on its being taken from the churn; a shallow wooden kit, twenty inches in diameter, in which it is washed; scales and weights; a stoneware jar for keeping the salt dry; jars, of the same material, for packing the butter in when salted; moulds for stamping it, if made up for the table or market; and covered dishes of glass or stoneware for containing the fresh product.

Immediately on being formed, butter should be taken out of the churn and put into the small tub. Cold water is then put into the flat kit, which is set in an inclined position, and the butter is thoroughly washed by being kneaded out and rolled up repeatedly on the bottom of the vessel; when this has been effected, lumps of it are taken in the hands, and beaten with the palms alternately, in order to deprive them of every particle of buttermilk. Were any of this suffered to remain, it would destroy the quality of the finest butter. because the casein and sugar embodied in it would undergo oxidation, the former becoming putrescent and the latter acescent. These decompositions would render the butter valueless, for, in addition to the putrefactive effluvia evolved, it would be almost entirely converted into the acids mentioned at page 395. The milky water being poured off and pure supplied, the butter is again washed and worked, and these proceedings are repeated until the water no longer comes off clouded.

If intended to be kept or disposed of in the fresh state, the mass is divided into lumps of the requisite weight, each of which is placed separately in the tub with water, afterwards clapped firmly with the hand, made into the desired shape, and finally moulded or *printed* according to custom, or the fancy of the operator.

This made-up butter is floated in a clear strong brine of salt and water, which is contained in jars provided with covers.

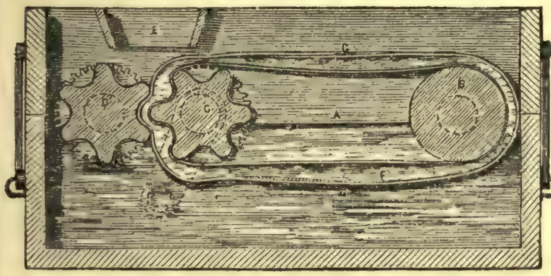
Reasons have been urged against the use of the hand in making up butter, and small wooden spades recommended instead; the employment of water has also been objected to, as it is said to deprive butter of its pleasant aroma. A person who has moist hands should never do the work of the dairy, as butter is very susceptible of taint, and its flavor will, doubtless, be injured by the perspiration; naturally cool hands, however, made clean by washing in warm water and oatmeal—*not with soap*—and then rinsed in cold water, will make up butter more free from acerb milk, and much more solid, than any instrument, whether of wood or any other material.

Cream is remarkable for the rapidity with which it becomes tainted with unpleasant odors. It is very necessary that the air of the dairy should be pure and often renewed, and that there should be no opening in any direction from which bad smells can come.

As to cold water injuring butter, there being no affinity between them, the former cannot dissolve any essential ingredient; and it is certain that water will more effectually unite with, and take away the milky fluid from butter, than could any manipulation in the dry state. Less handling may be necessary if the spade be *partially* employed in the first process of washing, for dividing, rubbing, and rolling it in the water.

America has lately made another addition to the farmer's mechanical aids, in the shape of a *butter-worker*, a longitudinal section of which is shown in Fig. 254.

Fig. 254.



The butter to be operated upon is placed in an endless sack or belt, G G, formed into the shape of a pulley-band, and in this position it is compressed and worked by passing between fluted rollers, the whole being immersed in a water-chamber, A, which is a rectangular box, so constructed that the upper half is movable. In it are bearings for the three cylinders, B C D; the first of which, B, is a plain carrier, while the two latter, C D, are grooved longitudinally, so as to give the butter a powerful indentation as it passes between them enclosed in the sack.

Salt being supplied through the hopper, E, drops upon the sack, and is worked into it by the operation of the fluted rollers.

The butter is admitted to, and removed from, the belt by two openings, formed with overlapping covers, which prevent its escape during the operation.

Motion is communicated by means of a winch-handle fixed upon the spindle of the roller, C, and the corresponding cylinder is driven in concert by spur-gearing.

SALTING.—If the butter is intended to be salted, it is somewhat differently treated; after being well washed, *et cetera*, it is weighed in the scales, the salt apportioned and immediately incorporated. The quantity of salt varies; when the butter is intended for immediate use, about half an ounce is apportioned to two pounds; but when it is to be kept, this amount is quadrupled, and each pound of butter receives one ounce of salt. At the Editor's farm, where a large quantity of butter is made weekly, which is highly esteemed by the purchasers, the salt is added in the proportion of a quarter of a pound to six pounds of butter, that is, about four per cent. of the chloride of sodium. The quality of the salt has a very material effect. Common salt contains a considerable quantity of other ingredients besides chloride of sodium; and as these are all bitter, they injure the taste of the butter, and prevent its keeping for any length of time. It is easy, however, to remove these impurities, by pouring two quarts of water upon one or two stones of the salt, stirring the whole well at intervals for a couple of hours, and afterwards straining through a clean cloth. The water which percolates is a concentrated solution containing all the impurities, but may be mixed with the food of cattle, or evaporated and used for common culinary purposes. The crystals which remain in the cloth are nearly free from impurities—these usually consisting of the soluble salts of lime and magnesia—and may be hung up in the cloth till they are dry enough to be mixed with the butter.

In the process of salting, the butter is spread out in the tub after the washing, and the salt, ground fine, is sprinkled over it, and the mass rolled up and rubbed down with the lower part of the palm of the hand, until the salt appears to be perfectly and uniformly incorporated. To insure this, only half the salt should be applied at once, and the butter lumped and set aside until the next day, when whatever brine or milk has exuded in the meantime should be poured off, and the other half of the salt added. The lump after this is put into the jar or firkin.

One great advantage of deferring the completion of the salting and the making up of the butter is, that without it, that firm, smooth, waxy texture, which is so characteristic of a fine product, is not so readily acquired.

PACKING.—Before packing butter, the state of the *kit* should be particularly examined. If made of stoneware, it is easily cleansed and rendered sweet. A wooden kit that has been previously used should be filled with water for some time, so as to render it tight by the swelling of the edges of the staves. It should then be repeatedly scalded with hot water and exposed to the air; and, just before being used, should be rinsed with cold water, and a slight quantity of salt sprinkled over its bottom.

New wooden kits require somewhat different treatment; otherwise the odor from the fresh wood will impart a disagreeable flavor to the butter. It is the practice in some parts of the country to fill them with garden mould, saturated with water, for some days, the mixture being occasionally stirred, after which they are thoroughly scrubbed and cleansed with hot water; then rinsed with cold water, and salted just before being used.

Butter is kitted in lumps, which are pressed firmly down upon each other, and also against the inside of the kit, so that no air can possibly be left in cells or interstices. The surface of the former churning of butter which had been put into the vessel, should be raised up into regular furrows, that the new portion may be thoroughly mixed with it. Any air that may have been left in the mass, or that finds access by the side of the kit, will *wind* the butter, that is, impart to it a rancid taste.

After the kit has been filled within an inch of the top, the exterior surface is made smooth and even, and covered with a piece of moistened white linen cloth.

BUTTER FROM SWEET CREAM AND MILK.—What has been stated in reference to the making of butter, applies particularly to that obtained from the unctuous or oily part of milk alone, and in the usual state, namely, after it has become sour by keeping; but butter can be procured from *sweet* cream, though churning renders the buttermilk as acerb as that from sour.

It has been alleged that butter of the finest quality cannot be produced from sweet cream, but it is well known from experience that it may be so made, not only of finer flavor, but also of better appearance. Were not such a product superior, would it be proverbially considered the greatest of luxuries at breakfast? Butter out of the churn, and before it is washed, is a delicacy, but *it must be used immediately*.

Butter is also made from the entire milk, which is usually allowed to stand until it becomes sour: a shorter time is required for its extraction than when the milk is sweet; but, in either of these cases, a large churn is required, and the agitation must be continued from one and a half to four hours, depending upon various circumstances. The butter so obtained is very good. The only evident objection to this method is the labor imposed in agitating so much milk, and in, consequently, having on hand a large quantity of buttermilk, which is, however, easily disposed of in towns; and although it does not yield so much profit in the country, is still very serviceable for feeding pigs. This method has its advantages in the uniform character of the butter it affords at all seasons, and in the certainty of attaining the proper temperature, which is required to be higher than that of cream—60° Fahr.—by the addition of warm water to the milk. Besides these advantages, one hundred gallons of entire milk have been proved to afford, in the summer months, five per cent. more butter than what would be yielded by the cream taken from the same quantity.

Churning from the whole, or *full* milk, is, comparatively, a simple process. The milk is at first poured into coolers, and from these it is drawn off by siphons into vats—sufficiently large to contain both the morning and evening meals—which are then put by to stand undisturbed till the whole acquires a sufficient degree of acidity. The time required for this purpose is subject to a little variation, according to the heat of the atmosphere, and the temperature of the milk-house. The point is ascertained by the thick *brat* or scum, which forms on the surface, becoming uneven.

All the milk operated upon at once is not of the same age, *but this does not affect the quality of the butter.*

QUANTITY OF BUTTER OBTAINABLE FROM MILK, *et cetera.*—The result of numerous trials made upon the milk and cream of cows considered to be *good* butter givers, has established the following as the average relation between the milk and its products, *videlicet:*—Eighteen to twenty-one pounds of milk give four pounds of cream, from which one pound of butter is produced. The proportion of the latter contained in such milk is thus from 4·762 to 5·555 per cent.

It is natural that the food given to the animal should greatly influence, not only the quality, as has been already noticed, but also the quantity of the butter obtained from a certain amount of milk. Thus, it is often not more than three per cent., whilst occasionally seven or eight may be found. The milk of an Alderney cow, in the possession of the Editor, was ascertained, by Mr. E. E. HOLDEN, to contain 6·788 per cent. of butter; and though this amount may seem overrated, it was, nevertheless, supported by practical results, since from fourteen gallons of milk, weighing about one hundred and forty-four pounds, 10·5 pounds of butter were obtained.

The yield of butter, from a very good cow, ought to be three hundred and sixty-five pounds in the year, or one pound per day. This is not a large *daily* produce, since cows have been known to give, for a limited time, as much as two pounds per day. Mr. HAROLD LITTLEDALE, of Liscard Farm, Cheshire, informs the Editor, that he had a cow which gave eighteen pounds of butter per week for some time during the summer months. The quantity of milk given per day was twenty-six quarts. If the butter be calculated from this at four per cent.—*vide* analyses, page 395—the daily yield would be found to be 2·678 pounds, giving a little more than eighteen and a half pounds per week, nearly what Mr. LITTLEDALE stated. Cows have been known to give twenty-two or twenty-three pounds of butter per week, but these are extraordinary instances.

In most districts, the average yield of a cow for the whole year is much less than a pound per day. In Devonshire, for the first twenty weeks after calving, a cow will give twelve quarts of milk daily, from which, by the method of scalding, a pound and a quarter of butter can be extracted.

In South Holland, a good cow will produce, during the summer months, about seventy-six pounds of butter. In the high pastures of Scaria, in Switzerland, the yield, during the ninety days of summer, is about forty pounds, or less than half a pound per day. In Holstein and Lunenburg, one hundred pounds are considered a fair return; and even in England, one hundred and sixty to one hundred and eighty pounds annually, or from eight to nine ounces per day, for ten months in the year, are accounted an average produce.

SCOTCH METHOD.—It may not be out of place to notice the methods followed in Scotland; and to do this more effectually, the operations, as conducted at a dairy farm of about thirty cows, situated twenty miles south of Edinburgh, will, wherever they essentially differ from those already described, be given. Mr. JOHN BALLANTYNE—its occupier—who has been an extensive dealer in Scotch butter for thirty years, is of opinion that, with the exception of sweet butter made in the neighbourhood of Edinburgh and Glasgow, there has been rather a deterioration in its quality during that period. There has been, however, a very decided improvement in the butter made of late years, by the farmers in the districts above mentioned, which he chiefly attributes to the method now adopted, of making the butter from the *entire milk;* the dairy farmer is thus enabled to carry on his operations in a regular and systematic manner, to churn the milk at exactly the proper period, to regulate the temperature, and, in short, to conduct the whole process on fixed principles.

Experience has fully proved that butter is yielded in the largest quantity, and of good quality, by the *entire milk*, that is, the milk from which the cream has not been separated.

Annexed is a brief sketch of the system which Mr. BALLANTYNE has successfully followed out:—In the summer season, the milk of the thirty cows is placed, at the morning milking, in two zinc coolers of sufficient capacity, and allowed to remain there to cool till the evening. It is then drawn off by siphons into vats, large enough to contain, not only this quantity, but also the evening's *meal*, or milking, which is mixed with it; and these two vats are then put by, to stand quite undisturbed, till the whole acquires a sufficient degree of acidity. The time required for this purpose varies a little, according to the heat of the weather and the temperature of the dairy-room. The point is ascertained, as already stated, by the formation of a strong thick scum on the surface, which then becomes uneven. The two succeeding milkings are treated in the same way—kept, of course, in separate vats—and, after standing for at least two entire days, the whole is put into the churns. By this arrangement, churning takes place three times in the week. Some of the milk is necessarily kept a little longer than other portions, but this does not affect the quality of the whole. The milk of Sunday and Monday is churned on the Thursday morning; that of Tuesday, Wednesday, and Thursday morning, on the Saturday; Thursday evening's, and that of Friday and Saturday, on Monday morning.

The churn used at this dairy is the *plunge*, or *upright*, which is considered superior to either the barrel or box-shape. Two churns are employed, driven by a walking-beam with two arms, attached to the water-wheel of the thrashing machine. Should there not be milk enough for both churns, one can be used, and, by shortening the stroke of the staff, it can be adapted to any quantity of milk—from twenty to one hundred Scotch pints—thus affording ample facility for churning at any intermediate time when necessary. The milk being carried in the vats from the milk-house, and put into the churns, as much hot water is added to it as brings the whole to the temperature of 65°. The churns are then set in motion, at the rate of thirty-eight or forty strokes in the minute, which is continued till the butter comes, requiring from three to three and a half hours. The velocity of the wheel is now diminished, by letting off part of the water, so that the agitators move very slowly. When this is effected, the dairymaid gathers the butter, and carefully squeezes out the milk; it is then put into a vessel filled with fresh spring water, well washed, and made up into half-pound rolls for the market.

In the winter season, when the cows are fed upon turnips, the system is changed—the coolers are dispensed with, and the morning's milk is carried from the *byre* and put into the churn closely covered up. The same is done with the evening's milk, and, next morning, hot water is added to raise the temperature to 65°, and the agitation commenced. By this method, both the butter and the buttermilk are said to be wholly free from any taste of turnips. The souring of the milk may be hastened by adding a little that is already acerb. The method of salting is as follows:—

The butter is drawn warm from the churn; and it is an invariable rule never to wash it, or dip it into water when intended to be salted. The dairymaid puts it into a clean tub, which is previously well rinsed with cold water, and there works it, with cool hands, till all the milk is thoroughly expelled. Half the allowed quantity of salt is then added, and well mixed up with the butter, and in this state it is suffered to stand till next morning, when it is again wrought up, any brine squeezed out, and the remainder of the salt added. It is then packed into kits, which, when full, are well covered up, and placed in a cool dry store—a small quantity of salt is usually sprinkled on the surface. The proportion of the condiment is half a pound to fourteen pounds of butter.

There are two great errors in the curing of butter in Scotland, which have caused its price to be lower than that of the foreign product, namely, using butter made from cream which is often too long kept, and not salting it *immediately* from the churn. Much of the butter cured in Scotland, especially in the Northern counties, is delivered in a fresh state by the farmer, and salted afterwards by the curer. Until the farmers learn to cure their own butter, the price of the Scotch article in the market will never equal that of foreign. If the Scotch farmers, who supply the London market, wish to obtain the best price, they must procure their butter from the entire milk, and cure it, fresh from the churn, in their own dairies.

Disadvantages attending the use of Zinc Vessels.—Mr. BALLANTYNE employs zinc coolers, no doubt with the view of augmenting the yield of cream. This metal ought never to be used, either for dairy or culinary purposes. When milk is allowed to repose in contact with this metal, a lactate of zinc is formed, as well as a compound of casein and oxide of zinc, both of which would give rise to nausea and vomiting if taken into the system. The Editor has found, by experiment, that a solution of sugar, which had stood a few hours in a zinc vessel in the heat, contained a considerable quantity of salts of the metal. Milk, it is well known, will become much sooner acid than a solution of sugar; consequently, if zinc be employed either in churns, as in America, or in dairy utensils, some of it will be dissolved, and thus a disagreeable taste imparted either to the butter or milk; moreover, its use should be prohibited, as a small amount of lactate of zinc will cause violent spasmodic vomiting. Milk being so delicate a fluid, and so easily affected by deleterious substances, great caution ought to be exercised in using in the dairy, any metallic utensil which might injure its quality.

The presence of zinc is detected by coagulating the milk with nitric acid, filtering, supersaturating with ammonia, and re-filtering if necessary; should this metal be contained in the milk, a white precipitate will result on treating the filtrate with sulphide of ammonium: to obtain an infallible proof of the existence of the zinc, it will be better for the experimentalist to evaporate the filtrate to one-half its bulk before adding the last-named reagent.

ADULTERATION OF BUTTER.—It is a remarkable fact that, in all the works treating on food, there is no information relating to the sophistication of this article.

The presence of both water and salt in butter to excess, cannot be regarded in any other light than as adulterations, and as these appear to be the only compounds now employed by the sophisticator, they will be here noticed.

From a tabulation of the results of the analyses of forty-eight samples of salt and fresh butter, by Dr. HASSALL, it is evident:—

Firstly, That all the *salt* butters tested contained, varying and generally, very large quantities of water, the amount ranging, with one exception, from 8·48 to 28·60 per cent.

Secondly, The *fresh* butters also held different and often considerable proportions of water, but in most cases very much less than the preceding, the range being from 4·18 to 15·43 per cent.

Thirdly, The quantity of *chloride of sodium* in the *salt* butters, varied from 1·53 to 8·24 per cent., showing that no fixed rule is adhered to in salting.

Fourthly, The *fresh* butters contained from 0·30 to 2·91 per cent. of salt.

Fifthly, The per centages of butter in the samples ranged from 67·72 to 96·93; hence some of the specimens were degraded with water and salt to the extent of twenty, thirty, and in one case to *nearly thirty-five per cent.*

The adulterating process is, to heat the butter until it melts, and then to stir it in water and salt until the whole is cold. Fifty per cent. of water may thus be incorporated; but, when retailed in small quantities, a considerable portion of this is lost.

A correspondent of the *Lancet*, being suddenly awakened at three o'clock in the morning, at the house where he was lodging, and perceiving a light below the door of his apartment, supposed the house to be on fire, and hurried down stairs, where he found the family busily occupied, and was jocosely informed that they were making Epping butter! For this purpose they made use of very inferior Irish salted butter, which was repeatedly aspersed with water, to free it from the chloride of sodium, after which it was frequently washed with milk, and the preparation was completed by the addition of a small quantity of sugar. The admirers of *fresh* Epping butter were supplied with this dainty, which yielded the ingenious vendor a profit of at least *one hundred per cent.*, besides establishing his shop as being furnished with the *genuine* article from a first-rate dairy.

In Brighton and other towns, lard, when cheap, is mixed with butter, as is readily perceived on tasting it, and there is reason to believe that, some years ago, flour was extensively used in several places as an adulterant.

Perceiving to what an extent salt butter is deteriorated with water and excess of salt, it is to be doubted whether any saving is effected by the use of this description of butter; although apparently cheaper, it is questionable whether, in reality, it is not dearer.

In whatever way, and to what extent soever, butter may be worked, some traces of buttermilk, and also of water, will be retained. This moisture does not, however, in *good* butter, exceed about one per cent., and the extent of the adulteration may, therefore, be known by weighing out a portion of the butter, heating it for some time in the water-bath, weighing it, and calculating the loss. A simple method of determining, pretty accurately, the amount of water, is to melt the butter, fill a small bottle with it, and place it near the fire for about half an hour; the water and salt will sink on account of their weight. In many cases it will be found that the water constitutes a fourth, or even a third of the article!

The proportion of inorganic salts, or ash, in the genuine article, is very minute, so that its sophistication with salt may at once be ascertained by heating a portion—the weight of which is known—to redness, and weighing the residue. The quantity of salt ought *never* to exceed five per cent.; therefore, anything above this may be regarded in the light of an adulteration.

CANDLE.—*Bougie*, French; *Talglicht*, German; *Candela*, Latin.—The manufacture and introduction of candles amongst the domestic conveniences of life, were in a manner no less productive of refinement in the taste and habits of communities than were those of soap and glass; and although the time at which they were first used is not exactly known, yet their consumption has been daily extended more and more, particularly of late years, notwithstanding the many and refined means devised by the inquiring spirit of the time, to illumine the hamlet as well as the metropolis—the dwelling of the humble mechanic, as well as the court of the monarch.

HISTORICAL NOTICE.—From the remotest period substitutes have been found for supplying by art the place of the great luminary of day, during the intervals of his absence; it appears, however, that not candles, but lamps, were generally used, in which oil was consumed in the way that suggested itself as most convenient. In Holy Writ many references are made to candles and candlesticks; and conformably to the idea now attached to these terms, a person might suppose that the manufacture discussed in the succeeding pages was no novelty in those remote ages; but, upon further consulting the same sacred record, it will be observed that these terms were used either in a metaphorical sense, or otherwise the translators have been at fault in rendering the meaning of a word in the Oriental tongue, by one which does not express the same in modern languages; for, that the candlesticks were intended to support lamps, not candles, is plain from the instructions MOSES received from the Almighty for making the golden *candle*stick—*And thou shalt make the seven lamps thereof, and they shall light the lamps thereof, that they may give light over against it.* Further testimonies, showing that olive oil was employed for those lamps, may be found in the Book of Leviticus, from which, as well as from the foregoing, it is plain that *candles* were not in use among the ancient Jews. The authors of Greece and Rome were equally ignorant of the candle, and although PLINY and other writers mention it, yet the only information to be gathered from them is, that their candle consisted of strings of flax, imbued and covered over with pitch or wax, probably not unlike those used by laborers at the present day, for laying down service or other pipes at night.

It is recorded by the above writer, that, at a later period, an attempt was made by the Romans to manufacture candles; but, instead of the graceful and ornamental cylinders employed now-a-days in the hall or drawing-room, theirs were only strips of papyrus or rushes, steeped in pitch and then coated with wax. That these were sometimes called torches, appears from that passage in the New Testament, where the evangelists speak of the Jewish soldiery going out to apprehend our Savior with *torches and lanterns*, *et cetera*.

It has been said that the manufacture of candles is coeval with the persecutions of the early Christians by the Roman emperors, particularly when the former took refuge in the catacombs from the fiendish rage of their oppressors; and this assertion is rendered more probable from the circumstance, that it is customary since that period to use candle lights in all the rites of the Romish Church. BECKMANN relates, on the authority of EUSEBIUS and others, that the Emperor CONSTANTINE, who ruled about the beginning of the fourth century, caused the whole of the city of Constantinople to be illuminated with lamps and *wax candles* on Easter eve; and FOSBROOK mentions that wax candles were made in the middle ages with wicks of twisted tow, varying from a very small size to fifty pounds in weight; these, he says, were cast in moulds called *longitudines*. As wax however, was scarce, it is probable that the houses of the humbler classes were but very imperfectly illuminated, if they were dependent upon candles made of this material. Various contrivances have been tried as substitutes, which demonstrate the gradual and elaborate manner in which perfection in any art introduces itself; of these the *rush-lights*, though of comparatively modern date, afford an example. It was not, however, until the introduction of tallow and animal fats, that the community could enjoy the luxury of cheap and convenient candle-light.

But leaving further historical researches to antiquaries and chroniclers, attention will now be devoted to the subject in a technical view, by stating the properties of those bodies employed in candle-making, as also the methods pursued in preparing the article. It is almost needless to give here a definition of a candle, which is merely a cylinder of combustible material—at present generally an animal or vegetal fat—in the centre of which some ligneous or fibrous body runs, serving, upon being ignited, to distribute as much heat as will convert the matter of the candle into vapor; this, when it comes in contact with the ignited part of the axis, undergoes combustion, and gives out light and heat—the consequences of strong chemical action. From this it is plain, that a candle, regarded in a chemical light, is simply a portable gas apparatus, wherein the generation of the vapors and their combustion are carried on simultaneously.

MATERIALS.—The manufacture of candles is not in itself an operation that requires very intricate machinery, or a great amount of knowledge; still, the materials are complex in their nature, and to render this article of service to the reader, whether or not he be a manufacturer, some account of these is necessary.

It will be seen from what has been premised, that the principal materials are fat, grease, sperm, and wax; hence it will be necessary to advert to the nature and properties of these bodies, and also to their constituents. The two great sources of fat are animals and vegetals; and although there are several classes, differing materially from one another in physical and other properties, yet they may all be included under three heads, namely, *oils*, *butters*, and *suets*. In a chemical point of view, the fats of animal and vegetal origin are nearly allied: the former are found in various states, according to the nature and habits of the animal yielding them: that of man, as well as of quadrupeds in general, is consistent, white, or yellowish; the fat of birds is finer, sweeter, and more unctuous; while that of fishes and cetaceous animals is, for the most part, fluid. Reptiles, insects, and worms, also contain fat, but in very small proportions. The regions of fat in animals are the cellular membranes in various parts of the body, but chiefly about the kidneys, the folds of the omentum, at the base of the heart, in the medeastinum, and the mesenteric web; also, upon the surface of the intestines, and in various other parts of the body. In fishes, it is found very frequently in peculiar reservoirs in the head and other places; and, in reptiles and insects, it is met with only among the viscera of the abdomen, in which it exists in separate portions, being scarcely discerned in the muscles beneath the skin.

There is some difference of physical properties in the fat of quadrupeds, which may be attributed to their food, as also to the age of the animal. In young beasts, it is white, insipid, and not very solid; in the full grown, it is firm and yellowish; and in the old, its color is deeper, its consistence varies, and it tastes stronger. In the herbivorous animals, the fat is almost inodorous, firm, and solid; while that of the carnivorous has more or less of a rancid smell and taste, and is more fluid than the other. Whether fat has been accumulated or constituted in the body by the vital functions of the organism, has been made a subject of keen controversy by chemists and physiologists. Some affirm that the generation of fat belongs exclusively to vegetal life—for plants are now well known to require food, and an atmosphere to breathe in, as well as animals—and that it is only assimilated by animals, not formed; while others maintain that fat is produced by the living organism of the animal, and principally by the deoxidation of the farinaceous portions of their food. The latter view is now almost universally adopted, as being the most conformable to daily observations. Much, indeed, might be said here on both sides, but as the question does not affect the business of the chandler, which is the subject under consideration, this is a point which will not be further dwelt upon. It has been already stated, that fats, from whatever source derived, are classed under three heads, namely, oils, butters, and suets: of these, oils are the most fluid, suets the most solid, and butters exhibit a medium consistency; but although many of the first class are fluid at ordinary temperatures and invariably the least solid, yet, according to the researches of CHEVREUL and BRACCONOT, they are composed of fluid and solid fats in variable proportions, as the annexed table represents :—

100 parts yielded	Fluid.	Solid.
Fresh butter in summer,	60	40
" " winter,	37	63
Hog's lard,	62	38
Ox marrow,	24	76
Goose fat,	68	32
Duck fat,	72	28
Mutton suet,	26	74
Olive oil,	72	28
Oil of sweet almonds,	76	24
Palm oil,	69	31

Of the several varieties which might come under the term fats, only those will be described which are connected with the manufacture of candles; namely, the animal fats, some of the more consistent oils or butters of vegetal origin, wax, *et cetera*—directing attention first to the composition of the animal substances.

Fats are not, as was formerly supposed, simple organic bodies, such as sugar, alcohol, or ether, but true chemical combinations of acid and base, both being of an organic nature. This important discovery was announced by CHEVREUL in 1813, to whose meritorious researches in this department, chemistry will ever be indebted.

Animal fats, butters, and some oils, are composed of three compounds; namely, stearin, margarin, and olein, and these again are constituted respectively of stearic, margaric, and oleic acids, united to a base to which CHEVREUL gave the name *glycerin*, on account of its peculiar sweetness: it is also called the *sweet principle* of fat.

Although by an assumption that fats had glycerin—a body first discovered by SCHEELE—for a base, the forementioned and many other chemists designated them as stearates, margarates, and oleates of glycerin, or of oxide of glyceril, yet it is a known fact, that when these bodies, or the natural fats wherein the three are united, are boiled with caustic alkalies, oxides of lead or zinc, they are decomposed without assimilating oxygen, or evolving hydrogen, into one or more fatty acids, and glycerin; but, on comparing the weight of such products with the original weight of the compound submitted to experiment, an increase is observed, which must arise from the assimilation of water. In order to explain the nature of this process, it was assumed that the fats are combinations similar to the ethers, and that glycerin, represented by the formula $C_3\ H_2\ O$, constituted the base of the compounds of which the fats are formed; but the elements of glycero-sulphuric acid, or sulphate of glycerin, produced by the direct combination of sulphuric acid and glycerin, show that the latter has the formula $C_6\ H_7\ O_5$, and, therefore, cannot be regarded as the base of the natural fats. It is obvious, also, that glycerin is not the base, from the circumstance that hitherto no natural fat has been prepared by combining the fatty acids with other elements. For these reasons it was assumed that the base contained in the fats, combined with the acids already mentioned, was an oxide of a radical having the composition $C_3\ H_2\ O$, and which BERZELIUS called lipyl. That glycerin is not a hydrate of oxide of lipyl is plain, from the circumstance that its combinations always contain three atoms of water more than the double atom of oxide of lipyl, and also from the fact, long since known, that the so-called haloid bases do not retain their water of hydration when they unite with acids. Against this doctrine, however, it is asserted, that the substance of the composition $C_6\ H_7\ O_5,\ H\ O = C_6\ H_8\ O_6$, known as glycerin, is, in the natural fats, united with stearic and the other acids, and that the bodies resulting from such a union are analogous to the ethers of the third class, which are formed from alchohol and oxygen acids, minus a certain number of equivalents of water; that the compound $C_3\ H_2\ O,\ H\ O$, has been known in the form of *acrolein* to possess a powerful degree of acridity, so much so, that its name has been deduced from this characteristic property. It might be possible in this case, however, for the elements of the hypothetical radical $C_3\ H_2\ O,\ H\ O$, constituting the remainder of the fat, to arrange themselves in a different form, whereby a compound having properties varying from the acrolein above-mentioned might result. However, it is more in accordance with the general opinion of chemists, to regard the simple fats as glycerides, or bodies composed of glycerin and an acid, minus a definite number of atoms of water, both from their analogy with the ethers of the third class, as was already explained, and from various other causes.

As to the proportion of stearin, margarin, and olein in the natural fats, great difference is observed. Human fat contains large quantities of margarate of glycerin, or margarin according to the old designation; this also forms the principal ingredient in goose fat and in olive oil. The more solid fats, such as mutton suet and tallow, are composed chiefly of stearin, whilst olein constitutes the main ingredient in those oils which remain fluid at low temperatures, particularly almond and rape oils.

STEARIN.—Stearin is obtained from mutton suet or tallow, by treating it with ether as long as anything is taken up; or by mixing mutton with six times its volume of ether, and subjecting the mass when cold to strong pressure, to remove the fluid constituents of the fat—olein: in either case, the stearin remains, but mixed with more or less margarin, from which it is exceedingly difficult to free it; this can be accomplished, however, by repeated re-solutions in hot ether and crystallizations, taking that part which solidifies first, and operating upon it in each experiment. It is a white substance, and as it deposits from alcohol, it forms snow-white, glistening scales; it is not greasy to the touch, is easily powdered, and melts at 143° Fahr., but does not crystallize on cooling; it readily dissolves in hot alcohol and ether, but is almost insoluble in water and ether in the cold. When submitted to dry distillation, stearin yields margaric acid, acrolein, acrylic acid, acetic acid, with oily and gaseous carbides of hydrogen, carbonic oxide, and some carbonic acid; as the heat is continued, the products of the distillation, which possess acid properties, diminish, and the empyreumatic oils increase in quantity, so that at length a distillate is obtained which does not redden litmus paper, and from which nothing is extracted by an aqueous solution of potassa. The residue in the retort becomes continually thicker, swells up, chars, and when the retort begins to attain a red heat, gives off yellow vapors, which sublime like chrysen, or some substance of a like nature; finally, from one to four parts of charcoal remain in the retort.

Regarding the composition of stearin and the other glycerides, GMELIN gives the following view:—The quantity of glycerin and fatty acids which form the glycerides, has been made out only in a few cases; but the researches of CHEVREUL and LECANU upon stearin, render it probable that this fat, by taking up eight atoms of water, is resolved into glycerin and two atoms of bibasic stearic acid. From analogy, therefore, it is supposed that, when the fatty acid is monobasic, one atom of glycerin corresponds to four atoms of acid; and, accordingly, that the glycerides are copulated compounds of one atom of glycerin and two atoms of a bibasic or four atoms of a monobasic acid, minus eight atoms of water. It is remarkable, however, that whereas ethers of the third class are neutral, because they contain only one atom of a monobasic acid to one atom of neutral substance, and copulated acids, on the contrary, are acid, because they contain two atoms of acid, the glycerides should, according to the views of GERHARDT, exhibit a neutral character, although they contain four atoms of monobasic acid. Whether this peculiarity can be satisfactorily explained by the feebly acid nature of the compounds existing in the fats, and by the circumstance that they must be supposed to contain twice as many atoms of water as can be separated from them, remains, for the present, undecided. At all events this difficulty need not compel the inquirer to suppose, as GERHARDT does, that the glycerides contain only two atoms of a monobasic acid or one of a bibasic, minus six equivalents of water; for, in the first place, this assumption does not explain the neutral condition of the fats, inasmuch as it still admits the union of two atoms of acid with one of a neutral body; and, secondly, it is controverted by the proportion of the glycerin to the soap acid, as determined by CHEVREUL and LECANU in the saponification of fats; namely, that a hundred parts of stearin yielded eight parts of glycerin and 96·86 of stearic acid, both being dried as far as possible, *per se*.

From the foregoing statement it will be remarked, that the atomic constitution of the glycerides is as yet undefined; but that the most probable formula, and that which best accords with known data, is one equivalent of glycerin and four of a monobasic acid, or two of a bibasic, less eight equivalents of water; the latter of which is attributed to be the composition of stearin. Thus—

	Atomic weight	Centesimally.
142 Eqs. of carbon,	852	78·74
134 Eqs. of hydrogen,	134	12·39
12 Eqs. of oxygen,	96	8·87
	1082	100·00

Formula: $C_6\,H_8\,O_6,\ 2\,(C_{68}\,H_{67}\,O_7) - 8\,H\,O =$
$C_{142}\,H_{134}\,O_{12} = 1$ Eq. of stearin.

STEARIC ACID.—This acid is readily obtained by saponifying pure stearin with potassa, decomposing the saponaceous compound with hot hydrochloric acid, collecting the flocculent stearic acid upon a filter, washing it with cold alcohol, and, when it is thoroughly edulcorated by this menstruum, it is dissolved in boiling alcohol, and the solution thus obtained set aside to cool, when the stearic acid crystallizes in white glistening needles or leaflets, which appear under the microscope as elongated lozenge-shaped plates. It is inodorous and tasteless, does not feel greasy to the touch, and dissolves in all proportions in boiling alcohol and ether, from which, as shown, it separates on cooling. At a temperature of 167° Fahr. it melts, and solidifies at 158°. In the solid state its density is 1·01, in the liquid 0·854; its alcoholic solution reacts slightly acid on blue litmus paper; it decomposes alkaline carbonates to the amount of one-half in the cold, and completely at the boiling point. It burns like wax, and forms the chief as well as the only ingredient in the manufacture of a highly-prized class of candles, to which reference will be hereafter made. When treated with an equal weight of nitric acid, specific gravity 1·273, it yields pure margaric acid. Stearic acid is bibasic, and, according to the foregoing, composed of—

	Atomic weight.	Centesimally.
68 Eqs. of carbon,	408	76·83
65 Eqs. of hydrogen,	65	12·24
5 Eqs. of oxygen,	40	7·53
2 Eqs. of water,	18	3·40
	531	100·00

Formula: $C_{68}\,H_{65}\,O_5,\ 2\,H\,O = C_{68}\,H_{67}\,O_7$.

MARGARIN.—This simple fat is best obtained in the largest quantities from human fat, but it may be procured from that of the goose by treating it with boiling alcohol, which dissolves the margarin, and parts with it again upon cooling in the form of a white flocculent powder; this, under the microscope, appears in very delicate needles, grouped so as to radiate from one point as a nucleus, thus composing a kind of whorl of fine capillary threads. It may be prepared also from ordinary fat by treating it with hot ether; and after the stearin separates in scales as the solution cools, the ethereal extract is to be evaporated to dryness and the residue dissolved in boiling alcohol, from which the margarin crystallizes upon cooling. It is separated from the last traces of olein by repeated crystallizations from the same menstruum, the crystalline matter being pressed each time between folds of bibulous paper. Thus prepared it is compact, tasteless, inodorous, and has a beautifully nacreous lustre in the crystallized state, whence LECANU called it margarin, from the Greek word for *pearl*. Saponified with potassa, it yields margaric acid and glycerin; it is soluble in ten parts of ether at 60° Fahr. When subjected to distillation, it is decomposed into numerous products, among which margaron may be found, also acrolein and acryllic acid, and several other carbides of hydrogen, both gaseous and liquid; its melting point is 118° Fahr.; it does not grease the fingers, and resembles stearin in almost every particular. Its composition is, according to the general formula for the glycerides, as annexed:—

	Atomic weight.	Centesimally represented.
142 Eqs. of carbon,	852	77·45
136 Eqs. of hydrogen,	136	12·37
14 Eqs. of oxygen,	112	10·18
1 Eq. of margarin,	1100	100·00

Formula: $4\,(C_{34}\,H_{34}\,O_4),\ C_6\,H_8\,O_6 - 8\,H\,O =$
$C_{142}\,H_{136}\,O_{14} = 1$ Eq. of margarin.

By saponifying with alkalies, a hundred parts of this fat afford—

Margaric acid,............	98·22 and
Glycerin,................	8·36 parts.

MARGARIC ACID is the compound associated with the hypothetical oxide of lipyl, mentioned on a former occasion, in the natural fats and in pure margarin, but which passes into glycerin. It may be obtained from pure margarin on saponifying by potassa, and decomposing the soap thus formed with an acid which precipitates it, washing the precipitate with alcohol, and finally purifying it by repeated crystallizations from its solution in boiling alcohol. It may be prepared from stearic acid, as before noticed, but when it is to be procured from the natural fats, the best way to proceed is the following:—Hogs' lard or olive oil is taken and saponified by potassa, and the clear viscid solution is decomposed with sulphuric or hydrochloric acid, by which the margaric, stearic, and oleic acids present in the fats are precipitated; this fatty precipitate must then be well washed with water, dried as thoroughly as possible, and pressed between folds of bibulous paper to remove the oleic acid. The solid residue now remaining, and which consists of margaric and stearic acids, must be dissolved in boiling alcohol, and set aside to crystallize; the stearic acid is the first to separate, and this affords a means for removing it from the margaric. In order, however, to isolate the margaric acid completely, this operation of crystallizing from the alcoholic solution must be repeated several times.

The product which has been thus prepared often contains some oleic acid, notwithstanding the numerous solutions and recrystallizations to which it may have been subjected: to remove this impurity, however, is a work of no great difficulty; for if the acid be combined with an alkali, and the saponaceous solution precipitated by acetate of lead, oleate and margarate of lead fall down, which, when collected and washed well to remove the potassa or soda salt, and afterwards treated with boiling ether, yield the margarate of lead quite pure, the oleate of this base being soluble in the menstruum. The margarate of lead may be decomposed either by carbonate of potassa, and the alkaline margarate thus formed treated with a strong acid, and the precipitate which separates crystallized from its alcoholic solution; or sulphuric acid may be poured upon the lead compound to remove the base, and then the mixture may be digested in boiling water, and the liquid acid decanted; when the fat solidifies it may be redissolved in boiling water and again allowed to cool, and this treatment continued several times in order to remove sulphate of lead and sulphuric acid; finally, it may be purified by alcohol.

This acid at ordinary temperatures is white, solid, and crystalline; when obtained from its hot alcoholic solution, the crystals are in the shape of very delicate nacreous needles, which, under the microscope, appear interlaced like tufts of grass, and arranged in ensiform plates, or grouped in star-like forms. It has neither taste nor smell, leaves on paper a permanent spot, which causes a semitransparency upon the application of a slight elevation of temperature; it is lighter than water, and, when thoroughly dried, fuses at 132·8° Fahr. When carefully distilled in vacuo, it is converted into margaron, carbonic acid, and a few other products; but if access of air be allowed, the decomposition is much more complex, and the products are more numerous.

Nitric acid, by the aid of prolonged digestion, decomposes it into succinic, suberic, carbonic acids, and water. It is composed of carbon, hydrogen, and oxygen, in the annexed proportions:—

	Atomic weight.		Centesimally represented.
34 Eqs. of carbon,..........	204	......	75·556
34 Eqs. of hydrogen,........	34	......	12·356
4 Eqs. of ogygen,..........	32	......	12·088
1 Eq. of margaric acid,....	270		100·000

Formula: $C_{34}H_{34}O_4 = C_{34}H_{33}O_3, HO$.

OLEIN.—The best way of preparing this compound, which is the principal constituent of oils and butters, is to operate upon those oils which are not drying, as they contain more or less margarin and stearin dissolved in the large proportion of fluid constituents. Drying oils, however, may be used to procure the olein; only it is required that they should be reduced to the freezing point previous to saponification, so that the most part of the margarin and stearin may solidify and be removed; the residual fluid can then be treated with ether, and the mixture subjected a second time to a very low degree of cold, to remove completely any traces of the other simple fats which might have remained after the preceding refrigeration. On removing the ether by distillation, pure olein is left. Expressed oil of sweet almonds is the purest natural olein, and next to it is rape.

Olèin is a colorless oily fluid at 0° Fahr.; on exposing it to the air it becomes rancid, and when decomposed by saponification with bases, it yields oleic acid and glycerin, together with small quantities of margaric acid derived from the traces of margarin, which are very often present in the olein, it being such a difficult task to remove the former completely. It has been observed, however, that the quantity of margaric acid afforded is greater than what the margarin present contains, and hence it is supposed that part of the oleic acid is transformed into it by saponification.

The rapid decomposition upon which crude fats, as taken from the animal, enter, is asserted to be occasioned by the change in the olein already alluded to: the removal of the olein from fatty matters employed in the preparation of candles, to which reference will be subsequently made, is performed with the avowed object of preventing the materials from turning rancid, as also to give greater consistency and more beauty and durability to the candle. PELOUZE and others assert that the substance which causes the rancidity is a definite body, and hence that there are two oleins; for that portion of drying fats which is liquid, but disposed to become rancid, differs from the liquid portion of the drying oils both in solubility and their behavior with peroxide of nitrogen—NO_4. This body transforms the former into elaïdin and elaïdic acid, while with the liquid portion of the drying oils no such action is observed. Olein is lighter than water, being about the density of 0·9; when subjected to a cold below minus 6° Fahr. it crystallizes in needles, and these crystals, collected and liquefied at the ordinary temperature, constitute the oil used by watchmakers. By distillation, olein affords sebacic acid and acrolein, and when acted upon by sulphuric acid, sulpho-oleic and sulpho-glyceric acids are formed; by exposure to the air it absorbs oxygen, becomes thicker, and liberates carbonic acid.

Olein is constituted of carbon, hydrogen, and oxygen, in the annexed proportions:—

	Atomic weight.	Centesimally represented.	Analysis of olein from human fat, by Chevreul.
150 Eqs. of carbon,.....	900	78·40	78·57
136 Eqs. of hydrogen,..	136	11·84	11·45
14 Eqs. of oxygen,....	112	9·76	9·98
1 Eq. of olein,........	1148	100·00	100·00

By saponifying one hundred parts with potassa, it affords—

Oleic acid,......................	98·26 parts, and
Glycerin,.....................	8·01 "

From the preceding, it will be seen that olein is composed of four atoms of a monobasic acid, and one of glycerin, minus eight equivalents of water, and is represented in the annexed formula:—

$$4\,(C_{36}\,H_{34}\,O_4)\;C_6\,H_8\,O_6 - 8\,HO = C_{150}\,H_{136}\,O_{14} = 1 \text{ Eq. of olein.}$$

OLEIC ACID is obtained from pure olein when this body is saponified with potassa, and the oleate of potassa thus formed decomposed by hydrochloric acid, which sets free the oily acid; this is to be collected in a clean vessel, washed with moderately warm water, and finally dried over chloride of calcium. It is also prepared by boiling olive or almond oil with potassa, and the potassa salt of the acid abstracted by cold absolute alcohol; on evaporating the spirit, and precipitating the aqueous solution by acetate of lead, an oleate of this base is formed, which is dried and then treated with boiling ether, to remove from the oleate of lead any margarate that may accompany it. When the lead salt freed from the ether is decomposed by carbonate of potassa, and the alkaline oleate thus formed decomposed by sulphuric acid, a brownish precipitate falls, which is oleic acid mixed with other products. For the purification of the brownish matter, GOTTLIEB directs that it should be treated with ammonia, the solution precipitated by chloride of barium, and the baryta salt repeatedly crystallized from moderately concentrated alcohol, till it forms a dazzling white, flocculent powder; lastly, the pure oleate of baryta is decomposed by tartaric acid, and the liberated oleic acid thoroughly washed with water. If the soap which is formed on boiling olein with potassa be decomposed by hydrochloric acid, and the crude product thus obtained be subjected to ebullition with oxide of lead, a combination takes place, and an acid and basic oleate of lead are formed, together with margarate of lead; the acid salt dissolves out in ether, leaving the other compounds insoluble. The ethereal solution is next mixed with its own bulk of water, and decomposed by hydrochloric acid, which throws down the chloride of lead, leaving the acid in solution to be obtained by careful evaporation. To purify it still farther, VARRENTRAPP recommends it to be saponified with carbonate of soda, the soap separated by chloride of sodium, and then decomposed by tartaric acid, and this process repeated until the acid becomes colorless.

Oleic acid, when cooled below 23° Fahr., becomes solid, and from its great contraction at this point it expresses the still oily portion present; it is very hard, and remains unaffected by exposure to the atmosphere. When the solid body is dissolved in alcohol, and the solution submitted to a great degree of cold, it separates in needles. At 57° Fahr. perfectly pure oleic acid forms a limpid, colorless, tasteless, inodorous liquid of the consistence of oil, and which exerts no acid reaction upon litmus paper, but when dissolved in alcohol or ether it reddens litmus powerfully. Its gravity at 60° is ·898; it is insoluble in water, but abundantly taken up by alcohol. Oleic acid in its fluid state rapidly absorbs oxygen, and becomes changed in its nature.

When distilled, it is broken up into numerous compounds, yielding carbon, carbonic acid, various carbides of hydrogen, capric, caprylic, and sebacic acids, the last being the largest product. As no other of the fatty matters here considered gives rise to sebacic acid except oleic acid, the detection of the latter is a sufficient guarantee of the presence of olein or oleic acid. By the action of nitric acid, oleic acid becomes solid and almost wholly converted into elaïdic acid; it unites with bases forming oleates; those of the alkalies are soluble in water, but the oleates of the alkaline earths and of the heavy bases are insoluble.

Its composition, according to the formula previously assigned for olein, is $C_{36}\,H_{33}\,O_3$, HO, or $C_{36}\,H_{34}\,O_4$, but VARRENTRAPP gives it as $C_{44}\,H_{41}\,O_5$, or $C_{44}\,H_{40}\,O_4$, HO, calculated from his analysis appended:—

	Atomic weight.	Varrentrapp.	Theory.
44 Eqs. of carbon,..........	264	76·73	76·52
41 Eqs. of hydrogen,........	41	11·89	11·88
5 Eqs. of oxygen,..........	40	11·38	11·60
1 Eq. hydrated oleic acid,...	345	100·00	100·00

This formula, however, disagrees in the proportion of its oxygen with the general formula, $C_m\,H_{m-3}\,O_3$, HO, to which the class of fatty acids belongs, and therefore the Editor would give precedence to the first-mentioned formula, which harmonizes with this, and also with the views previously taken of the fatty bodies.

Besides the materials already mentioned, other substances are employed in the manufacture of candles, and before entering upon the minutiæ of that part of the subject, it may be well to describe their peculiarities and properties. The compounds alluded to, are spermaceti, coco-stearin or cocinin, palmatin, wax, and paraffin.

SPERMACETI is the fatty matter found in the head of the *Physiter Macrocephalus*, and some allied species of whale, in the various receptacles of the bones of this part of the animal. During the life of the creature the spermaceti is fluid, but after its death it congeals into a white crystalline mass. When purified from the oily matter, which may be regarded as isomeric with the solid part, though uncongealed, it forms a brilliant, pearly-white solid, of a lamellated structure.

The best method of separating the oily part and other bodies from the pure spermaceti, is to submit the crude substance to strong pressure, which removes the most part of the oil, and by boiling the residue with weak solutions of caustic potassa, the remaining portion is taken up; afterwards, the residue is washed with water, then melted in the boiling liquid, and cast into moulds or blocks. When it solidifies, it exhibits a beautiful lamellar, crystalline texture, especially if the yet fluid portion in the centre of the mass be allowed to flow out of the concrete part. Spermaceti is lighter than water, its density being 0·943 at 60° Fahr.; it is but slightly soluble in alcohol, a hundred parts of which, of 0·821 density, take up only three and a half parts, and of these 0·9 falls down in crystalline plates as the liquid cools. Boiling ether dissolves it in large quantities, the ethereal extract congealing in the cold. Thus obtained, it melts at 112° Fahr.; still it is not regarded as pure, but as a compound of cetin and oil, the former being the chief ingredient, and the latter being isomeric with the solid part of the fatty matter. To obtain the cetin, the crude spermaceti is treated several times with boiling alcohol, which parts with it in crystals as the menstruum cools; it is necessary to repeat the operation, as long as there is any oil abstracted; finally, it should be crystallized from ether, till the fusing point rises as high as 120° Fahr. Cetin contains the elements of cetylic or ethalic acid, and oxide of cetyl or ethal; but it is supposed by SMITH, who examined this body, and showed it to consist of the preceding compounds—thus disproving the assertion that it contained margarin and olein—that it is not a chemical combination of those bodies, for the usual characters of compounds of acid and base could not be observed in the substance; however, since oxide of cetyl or ethal possesses the characteristics of an organic base, and the other body into which the cetin is resolved, namely, ethalic acid, has distinct acid properties, the substance is represented as cetylate of the oxide of cetyl, the formula of which is $C_{32}\,H_{33}\,O + C_{32}\,H_{31}\,O_3$, or $C_{64}\,H_{64}\,O_4$; that is, one equivalent of oxide of cetyl, and one equivalent of cetylic acid.

When spermaceti, or pure cetin, is saponified with potassa, cetylate of potassa and ethal are the only bodies formed; considerable time is required to bring about its combination with the alkali, which shows that no acid, as such, is present in cetin. By distilling cetin in close vessels at the boiling point of mercury, both these compounds pass over.

DUMAS and PELIGOT regard spermaceti as the oleo-margarate of ethal, the composition of which is assumed by these chemists to be as follows:—

2 Eqs. of margaric acid,..........	$C_{68}\,H_{66}\,O_6$
1 Eq. of oleic acid,..............	$C_{44}\,H_{40}\,O_4$
6 Eqs. of ethal,..................	$C_{96}\,H_{102}\,O_6$
1 Eq. of oleo-margarate of ethal,..	$C_{208}\,H_{208}\,O_{16}$

Spermaceti is largely used in the manufacture of candles, and will, therefore, be recurred to under that head.

COCO-STEARIN, or COCININ, is a constituent of the oil extracted from the coco-nut, from which it is obtained in the crude state by pressure. It may be purified by dissolving it in boiling alcohol or ether, as already described under stearin, from which it crystallizes on cooling. Cocinin is a white, solid, crystalline body, possessing a specific gravity of 0·925; it is insoluble in water, and only sparingly dissolved by cold alcohol, but soluble in alcohol and ether at the boiling point in large quantities. Its melting point is 77° Fahr.; when saponated with potassa, it is resolved into coco-stearin or cocinic acid and glycerin. It is used to some extent in the manufacture of composite candles, as will be shown further on.

To prepare the acid, the stearin is boiled with caustic potassa, and the resulting soap decomposed by hydrochloric acid, which disengages stearic and oleic acids, the latter being afterwards removed by pressure; it is necessary, however, to have recourse to saponification, and subsequent pressure a second or third time, to procure the acid in its purity, which, when obtained, is to be crystallized from its solution in hot alcohol.

It is a white, hard, brittle, inodorous substance, and almost transparent at the edges. It fuses, according to BROMEIS, at 95°, and forms, on cooling, an amorphous, diaphanous mass like porcelain; BRANDE states its fusing point to be 80°. At first it appears to have but little taste; after a while, however, it is slightly acrid. It is insoluble in water, but alcohol and ether dissolve it in all proportions.

BROMEIS gives the following as its composition:—

		Centesimally represented.	
	Atomic weight.	Theory.	Bromeis.
26 Eqs. of carbon,......	156	72·80	72·82
26 Eqs. of hydrogen, ...	26	12·14	12·23
4 Eqs. of oxygen,.....	32	15·06	14·95
1 Eq. of cocinic acid,...	214	100·00	100·00

Formula: $C_{26}\,H_{26}\,O_4 = C_{26}\,H_{25}\,O_3,\ H\,O$.

PALMATIN.—This peculiar fatty matter, which constitutes about thirty per cent. of the palm oil of commerce, is extensively employed in making candles. It is purified from the other constituents of the crude oil after being bleached, by submitting this to much pressure, whereby the olein is in a great measure removed; but its ultimate separation is performed by washing the expressed matter with hot alcohol, and finally crystallizing the residue from its solution in hot ether. The fused palmatin, upon cooling, congeals into a friable mass very similar to wax. From the researches of STENHOUSE, it appears that palmatin is composed according to the formula $C_{35}\,H_{33}\,O_4$, an equation which corresponds with the view taken of the fats at the commencement of this article; namely, of their being compounds of oxide of lipyl and a fatty acid; for it is known that palmatic acid is $C_{32}\,H_{31}\,O_3$, leaving the body $C_3\,H_2\,O$, which is the composition there assigned for the oxide of the radical mentioned.

		Centesimally represented.
	Atomic weight.	Theory.
35 Eqs. of carbon,.............	210	76·36
33 Eqs. of hydrogen,..........	33	12·00
4 Eqs. of oxygen,............	32	11·64
1 Eq. of palmatin,............	275	100·00

PALMATIC ACID is obtained in the usual way for procuring the other fatty acids; namely, by saponifying palm oil, especially the older kinds, with potassa, and decomposing the resulting compound in the ordinary method with an acid, then subjecting the precipitate to the action of boiling alcohol, which dissolves it, and deposits it afterwards in crystalline leaflets, as the liquid cools; finally, it should be submitted to pressure to remove the oleic acid, and afterwards crystallized from ether. It is a beautiful white substance, only sparingly soluble in cold, but more abundantly in hot alcohol; it resembles in a great measure margaric acid, both in its crystalline form and melting point, which in the case of palmatic acid is also 140° Fahr. When heated to about 572° Fahr., and dissolved in alcohol, it no longer separates in lamellar plates, but in mammillated masses, which, however, have the same composition as the original. It suffers distillation without undergoing much decomposition.

The hydrated acid, according to STENHOUSE and FREMY, is composed of—

	Atomic weight.	Centesimally. Theory.	Stenhouse.	Fremy.
32 Eqs. of carbon,.......	192	75·00	75·1	75·20
32 Eqs. of hydrogen,....	32	12·50	12·4	12·67
4 Eqs. of oxygen,......	32	12·50	12·5	12·13
1 Eq. of palmatic acid,.	256	100·00	100·00	100·00

WAX.—By this term various compounds, derived both from animals and vegetals, and differing both in composition and physical properties, are designated, but that which is used in candle-making is obtained from the former, and bears the name of bees' wax. In China, wax is secreted by a kind of insect which feeds upon a species of tree, one of which, as appears from various writers upon that country, is the *Rhus succedaneum*. The *Coccus ceriferus* is another insect which elaborates wax. These facts are of great interest to physiologists, for they assist to demonstrate the origin of it in the animal body. Vegetals afford wax likewise, in which state it may be regarded as a concrete oil; the fecula of the cabbage is chiefly wax; it is found also in the pollen of flowers, in the skins of plums, and in many other stony fruits. The green varnish observed on leaves of trees is formed of this substance; and it is occasionally met with even in the juice of some trees, such as the cow-tree, the palm, and the cork-tree. The berries of the *Myrica*, *Augustifolia*, *Latifolia*, and *Cerifera*, contain wax in large quantities. For a considerable period it was an undecided point among chemists and physiologists, whether the insects which afford wax collected it from vegetals in its ordinary state as a part of their food, and voided it again unchanged, or whether they produced it by the action of their digestive or other organs: the experiments of HUNTER and HUBER, however, prove that the insect can produce wax; and that it is the work of a certain organ which forms a part of the small cysts or sacs, situated on the sides of the median line of the abdomen of the bee, which may be observed by raising the lower segments of this part of the insect's body, having small spangles of wax arranged in pairs upon each of them. All bees, except the males and queen, in which they are never observed, are provided with eight of these sacs or tunics. Bees which are fed upon sugar, elaborate large quantities of wax; hence the supposition of its being exclusively procured from vegetals is no longer maintained.

Wax is produced in moderately large quantities in England, and it is considered to be far superior to the produce of other countries; the quantity is, however, too small for its requirements, and, therefore, a great deal is imported from Gambia, Magadore, Ceylon, Singapore, North America, and Brazil. The Gambia wax is difficultly bleached, and is apt to turn brown in a short time. The wax which is sometimes imported from Brazil, and is produced by a kind of black bee which hives under ground, is soft, and exceedingly tenacious, and the usual bleaching process seems to have no effect upon it. It is of a dark mahogany color.

As obtained from the honeycomb of the bee, and from its other sources in the natural state, wax has various shades of color; that procured by pressing out the liquid contents of the honeycomb, and washing and melting the residue, is yellowish. The honey that is deposited in the cells communicates a mellifluous odor; for the wax of those parts of the comb which contain none of this fluid, does not possess this characteristic. To purify wax from the extraneous matters which generally accompany it, the usual method followed is to melt it in hot water, or by steam, either in a copper, tin, or wooden vessel, and draw off the supernatant oily-looking fluid into an oblong vessel, the bottom of which is perforated, for the purpose of distributing the liquid material over horizontal wooden cylinders, which are kept revolving half immersed in cold water. The fluid wax is by these arrangements readily solidified in thin sheets or ribbons, which are afterwards exposed to the bleaching action of air, light, and moisture. On the large scale, this bleaching is effected in a way analogous to the old method of bleaching linen. A field with a Southern aspect is selected, on which a number of uprights are fixed, and these are used to support strips of canvas, or other cloth, fastened horizontally to each of them; upon this cloth the thin shreds of wax are laid, and occasionally watered till the yellow color disappears. The field should be as sheltered as possible, in order that the light leaves of wax may not be blown off the cloths. Attendants repeatedly turn the leaves, so that each side may receive equal benefits from the air and light, and water them at regular intervals; when the color seems stationary, and no further improvement appears to be effected, the wax is collected, fused with water, and treated in every respect as before, and again brought to the bleaching ground, where the process is continued till the wax becomes sufficiently white. For greater security against the wind, it is usual to draw a net over the wax spread on the cloths after they are properly watered. In France, where the bleaching of wax forms a considerable branch of industry, bitartrate of potassa is used for the purpose of effecting the purification more quickly; it is mixed with the water in the first fusion of the wax, and after the latter has been drawn off and washed, and then cast into thin laminæ, the process of bleaching already alluded to is either wholly unnecessary, or is, at least, much shortened.

Neither chlorine gas nor bleaching powder can be used in decolorizing wax; for these substances render it brittle, and, when used for candles, prevent its burning well, in consequence of a portion of chlorine remaining united with it even after repeated washings. INGENHOL publishes the following recipe for bleaching wax:—

The wax is to be melted, and two ounces of pulverized nitrate of soda added to every pound weight, and then one ounce of strong sulphuric acid, previously diluted with eight ounces of water, is gradually poured in, the whole being warm, and stirred while the liquid is being added. The vessel wherein the ingredients are brought together should be rather large, as the mixture swells up considerably.

After allowing the wax to cool a little, the vessel is filled with boiling water and set aside for the wax to solidify; when cold it is removed to another vessel and treated with a further charge of hot water, and again cooled; this operation is repeated till all the sulphate of soda and any trace of nitric acid are removed. Should nitric acid remain in the wax, it would be apt to communicate a brownish yellow color, which is objectionable.

Pure bees' wax is white, transparent, tasteless, inodorous, and insoluble in water; it fuses at about 145° Fahr., and softens, so as to be kneaded and moulded at 85° to 90°; it has a specific gravity of ·960 to ·966 when solid, but in the melted state, at a temperature of 178°, the density is 0·834, and at 200° it is only ·8247. At 32° wax is hard and brittle.

When treated with boiling alcohol repeatedly, a considerable portion of it is taken up, leaving from ten to twenty per cent. of an insoluble waxy substance called myricin, which is much heavier than ordinary wax, being about the same density as water. The alcoholic solution on cooling deposits the extracted matter; it is called cerin, and when well purified by repeated crystallizations from alcohol, melts at about 162° Fahr. It appears from Brodie's investigations, that this body is chiefly composed of an acid which he calls *cerotic*, and he suggests that the cause of this being overlooked by former investigators in this department, was their not taking sufficient pains to purify the crude alcoholic extract by the repeated re-solutions and crystallizations which it requires, and also because, when wax is submitted to distillation, scarcely a trace of the cerotic acid remains, although when distilled alone it volatilizes unchanged. In a sample of Chinese wax scarcely any cerotic acid was found; but the alcohol of this acid was discovered by fusing the wax with solid potassa in order to saponify it, dissolving the soap in boiling water, and precipitating the milky liquid thus obtained with chloride of barium, then washing the baryta salt with boiling alcohol, which takes up the impure substance, but parts with it upon cooling. Successive re-solutions and crystallizations from alcohol purify it, so that its melting point may be raised to about 174° Fahr. This substance is called cerotin. By the distillation of cerin, numerous oily products passed over, some of which were acid; and as the distillation was continued, carbides of hydrogen were evolved, but no margaric acid, and only mere traces of paraffin could be observed.

On investigating the myricin remaining, after the removal of the cerin by alcohol, two substances were extracted from it; *melissin*, from which melissic acid was procured, and *palmitic acid*. The melissin was obtained on saponifying the myricin by fusing with potassa, dissolving the soap in boiling water, and throwing down the baryta salt of the acid by chloride of barium. When this substance is washed with ether, the melissin which had precipitated is extracted, and is purified by repeated crystallizations from ether till its melting point is 185° Fahr. By subjecting myricin to distillation, the first portion that passes over is chiefly composed of acids, and afterwards carbides of hydrogen are eliminated, some of which solidify; if the distillate be saponified and treated as in the preceding instances till the baryta salt is pure, then, by decomposing it with strong acetic acid, palmitic acid separates.

The solid part of the distillate, and which was removed from the solution of the soap by filtration, was found, on being further purified, to have a melting point of 133° Fahr.; this is called *melen*. A similar body was procured from the distillation of Chinese wax, melting at 136°, but of a different composition, to which the name cerin was given. These solid products of the distillation were regarded as paraffin, and although they agree with the formula, C_m-H_m, given to this body indiscriminately, yet, as the melting point of these substances varies from that of the paraffin of wood, Brodie considers them as quite distinct bodies, and preferred the forementioned names.

This investigation shows that myricin and cerin, which were supposed by Ettling to be isomeric bodies, are not so; further, that the statements of Hess and a number of other chemists, who regard wax as a simple substance, having the composition $C_{20}\ H_{20}\ O$, but capable of oxidation, is untenable; and also, that stearic acid cannot be procured from it when distilled, as was stated by Lewy. Brodie's researches on this subject are most conclusive.

Annexed are the names and formulæ of the substances which have been described :—

Name.	Formula.
Cerotic acid—Cerin,......	$C_{54}\ H_{54}\ O_4\ = C_{54}\ H_{53}\ O_3,\ H\ O$
Cerotin—Hydrated oxide of cerotyl,....... ...	$C_{54}\ H_{56}\ O_2\ = C_{54}\ H_{55}\ O,\ H\ O$
Ceroten—Paraffin,........	$C_{54}\ H_{54}$
Melissin,................	$C_{60}\ H_{62}\ O_2 = C_{60}\ H_{61}\ O,\ H\ O$
Melissic acid,............	$C_{60}\ H_{60}\ O_4 = C_{60}\ H_{59}\ O_3,\ H\ O$
Melen—Paraffin,..........	$C_{60}\ H_{60}$
Palmitic acid,............	$C_{32}\ H_{32}\ O_4 = C_{32}\ H_{31}\ O_3,\ H\ O$

Paraffin.—This body, to which allusion has been made in the foregoing pages as being a product of the distillation of wax, was discovered by Reichenbach, who named it. It is best obtained from beech tar by distillation. Among other products a heavy oil collects in the receiver, which, after repeated distillations, is treated with strong sulphuric acid, in small portions at a time, till the mixture assumes a black color and dilute consistency. The liquid is to be maintained at a temperature of 212° for a short time, and then kept at 122° for twelve hours or longer, and at the end of that period a colorless oil will be found floating on the surface, which, when siphoned off and cooled, affords the paraffin as a concrete scum. It is purified by washing and pressing between folds of blotting paper to remove the oil; and finally, it should be dissolved in different portions of anhydrous alcohol, from which it separates in scales on cooling.

Paraffin is a crystalline, tasteless, colorless, and inodorous substance; it is slightly flexible, and not unctuous to the touch. When heated to 112°, it fuses to a colorless transparent oil, and at higher temperatures boils and distils without change. Its density is 0·870. It does not saponify with alkalies; neither have acids, chlorine gas, nor potassium any effect upon it; camphor, naphthalin, benzoin, or pitch, do not unite with it; but it enters into combination with stearin, bees' wax, colophony, and cetin, and readily dissolves in oil of turpentine and in naphtha. Ether dissolves it in large proportions, and the solution concretes on cooling. Its vapor burns with a beautiful white light. Paraffin has been found in some fossils; it is obtained from the products of the distillation of bituminous schist, petroleum, and wax, but these may have different properties, although composed proportionally of the same elements, as was shown in the case of that procured from wax. It has the same per centage composition as olefiant gas; hence its great utility in the manufacture of candles.

Purification of Materials.—In the foregoing pages, the chief illuminating materials of fats are described, and their properties given, as well as the other compounds that are used by the candle-maker; but as they cannot always be employed in their purity as there mentioned, and as some tact and skill are required to prepare them even comparatively free from the other useless or injurious matters associated with them in the natural state, attention will now be directed to the means by which this can be effected; and the better it is done, the more beautiful in every respect will be the candles which are made from such bodies. In the case of animal fats, the extraneous bodies that require removal are cellular tissue and membranes, blood, blood-vessels, chylous matter, *et cetera*. From these, the fatty materials can be extracted by heat and pressure, and when such heat and pressure are applied in the manner about to be described, the results are of a good quality; but when the raw products are allowed to remain for a more or less protracted period before being submitted to those processes, putrefaction of the nitrogenous matters sets in, giving a bad odor, which is very disagreeable and not easily eradicated.

The action of heat upon the animal fats will perhaps be better understood from the nature of the aggregation of these bodies, which, according to Raspail and others, are composed of very small, partly polygonal, and partly reniform particles, connected by a very thin membrane. Mechanical agency is sufficient to break up this integument, and if the mass be treated with water, and the liquid portion allowed to percolate through a fine brass wire or hair sieve, the small particles will remain floating upon the water, and ultimately collect, forming a white granular mass of a crystalline appearance like starch. Exteriorly, the globules appear to be composed of a solid matter of the nature of stearin, the interior being made up of olein or elain, which exudes, and may be abstracted by pressure: strong alcohol dissolves this fluid portion.

Fats of different animals vary considerably in point of utility to the chandler: the best for his use are beef and mutton suet, the tallow of goats, and also hogs' lard; other products are sometimes serviceable, and used to a considerable extent in preparing the inferior lights. Beef fat or tallow has a yellowish color, and a peculiar odor; it is hard and brittle, dissolves in about forty parts of alcohol, and melts, according to Dr. T. Thomson, at 100° Fahr. It contains about seventy-five per cent. of white, crystalline stearin, which fuses at 111°, and may be cooled down to 102° before congelation commences. When this occurs, however, the temperature rises to 111°, and remains so till the whole becomes solid. Boiling alcohol takes up about fifteen or sixteen per cent. The tallow of commerce is generally mixed with mutton suet.

Mutton suet or sheep fat, when fresh, has very little odor, though it acquires, in a short time, a rancid smell, probably from some traces of albuminous matter putrefying, and also of the olein decomposing; this smell is stronger if the suet be exposed to the air. It fuses between 100° and 106° Fahr.; it is white, hard, and brittle; quite insoluble in water, and only partially so in alcohol, a hundred parts of which, at a density of 0·820, and boiling temperature, take up only about 2·3 of the fat; the solution deposits stearin upon cooling. Mutton suet concretes at 100°, but, by solidifying, the heat is raised to 111° Fahr.

Lard or hogs' fat has of late years been employed in the manufacture of candles, but the olein is first removed by appropriate means, which will be subsequently pointed out. The quality of lard varies very much, owing, as is supposed, to the nature of the animals' food; for instance, the fat of those hogs that are fed upon potatoes or grain is hard, and possesses great body. When the animals are fed upon malt, their lard is next in quality to the preceding; but the fat of such as consume distillers' wash contains very little body; besides, it is soft, oleaginous, and of a yellowish color.

Hogs' lard fuses at 81° Fahr., its specific gravity is 0·938 at 50°. Boiling alcohol takes up from 2·8 to three parts of the fat. When saponified with alkalies, and the soap decomposed, it affords about ninety-five per cent. of a precipitate composed of stearic, margaric, and oleic acids; and nine parts of glycerin are obtained from the filtrate. Only the stearic and margaric acids enter into the composition of the candles made from this material; these, however, form thirty-eight per cent. of good lard, the remainder being olein and tissue. The best quality of lard, when taken fresh from the animal, is white, but after exposure to the air it assumes a yellow color.

Goats' fat is much richer in stearin than any of the preceding; its odor is most singular, arising from a compound peculiar to this fat, called *hircin*.

To separate these fats from the cellular tissue and other matters, recourse is had to heat, which is the principal agent; the operation is technically termed *rendering*, and the department where the work is conducted is called a *foundry*. Although the process of rendering requires nothing further than the application of a proper temperature to separate the fatty particles from the adipose tissue, for the regulation of which the knowledge of the fusing point of the fats is the main director, yet, when the materials have contracted a bad odor, very much depends upon the proper application of the necessary temperature, and the general care which should be exercised, so as to insure the greatest degree of purity in the materials, as far as it is possible to attain it. Various methods of working are followed, both by the regular refiner, and the chandler who carries out the business on his own premises.

The best time to render animal fat is while it is fresh, and for this reason the tallow is collected immediately from the abbatoir, or from the butchers' stalls, as soon as possible; for, when allowed to remain for a time before being worked, and perhaps in an undried state, it undergoes a kind of fermentation highly injurious to the after success of the working. In many parts, the butchers form associations for the purpose of rendering the tallow, by which they secure to themselves the advantage of making sale of the article, and obtain a profit on their labor; whereas, without this arrangement, the tallow may bring but very little remuneration. Where these conveniences do not exist, the tallow or lard is strung up to dry, but still the blood and other nitrogenous matters suffer putrefaction in a very short time. For those who may have sufficient capital, the best way would be to purchase the crude material and purify it; by so doing, they will be enabled, with skill, to prepare better articles, and more experience will thus be acquired than if they were to purchase the materials from the regular purifiers.

The necessary requisites of a foundry for purifying tallow and other fats are, a drying-house, steaming vessels or boilers, tubs, and presses. When the fat is purchased, if it be very fresh, it is strung up in the drying-house for the purpose of driving off any moisture; by this means it is hardened, and the operation of mincing before subjecting it to heat is thus greatly facilitated. A well-aired chamber is always selected for the drying; in this room, long horizontal rafters are supported either by cords or upright pillars, and upon them the sheets of rough tallow are strung till they become dry. After the exsiccation, which should be effected as speedily as possible, the tallow is minced by appropriate machinery, impelled either by steam or the hand; when the foundry is large and well regulated, the work is performed by the aid of steam, but in small establishments the tallow is chopped by a lever knife fixed upon a table in one end of the drying-room.

Fig. 255.

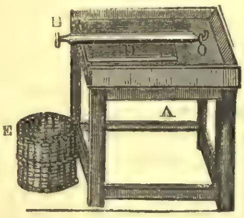
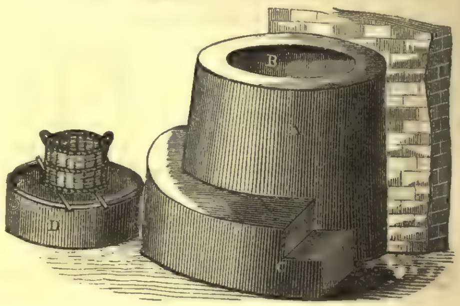


Fig. 255 represents one of these chopping machines: A is a table on which the knife, B, is fixed at C; the knife is propelled horizontally by the hand with a chopping motion, so as to move in an arc of a circle, upon a piece of beech-wood, D, screwed on the table, which it protects from the wear and tear of the knife: it can be renewed when it becomes worn out by continued hacking. The minced tallow is collected in a basket or other recipient, E, and thence taken to the boiler for the purpose of melting it. In some of the smaller factories, the boiler is a copper vessel placed over a fire, the flame of which comes in contact with only its bottom, in order that the melted fat may not acquire a black color from any parts which might be carbonized were the heat to circulate round the vessel. To keep the unrendered matter from contact with the metal, a bath of melted material is always retained in the bottom of the boiler, or a layer of water. Fig. 256 represents an apparatus such as is here alluded to: B is the boiler, made of copper, enveloped in brickwork, A, and heated by a fire placed without the wall of the room. The lower part of the boiler is generally that of an inverted cone, but its sides slope inwards towards the mouth, to prevent the inconvenience which would arise from the spirting of the melted suet. Around the walls of the boiler, a balcony, C, is raised for the convenience of the operator. The chopped tallow is thrown into the boiler, and the fire lighted so as to communicate a moderate heat; and as soon as the bath of rendered tallow on the bottom of the copper becomes melted, the entire contents are kept regularly stirred by the workmen with a long instrument like an oar, till the material is completely extracted. When this is accomplished, the liquid is ladled out into a large tub, D, whence it is afterwards removed to small ones, arranged on the floor of the foundry at equal distances from the boiler. A filtering apparatus is placed upon the tub, to collect any portion of the solids which may be taken from the boiler: this medium is generally of the simplest construction, such as a wicker or wire basket thickly woven; but it would be better to use a brass wire-gauze sieve, which would prevent the solid particles from passing through, and cause no waste of the melted material. Some persons, to effect a better separation of the solids, press a filter sieve of a coarser wire into the caldron, and then ladle out the liquid which rises through its meshes, and pass it through a finer sieve placed upon the tub. Before distributing the melted fat into the smaller tubs, the contents of the larger one are allowed to rest for some time, for the purpose of depositing any impurities that may have passed through the sieve, but must not be allowed to solidify.

Fig. 256



After all the liquid fat is removed, the membranous and other solid matters remaining in the boiler, called cracklings or *boulée*, still retain some fat, to remove which they are taken out and thrown into boiling water; this melts the fat, and causes it to float upon the surface, when it may be ladled out and boiled a little longer, if it be thought necessary, to remove water from the suet; the boulée remaining on the sieve, and deposited in the tub, is treated in a similar manner, by which the principal part of the fat is extracted; the whole of it, however, cannot be separated by this means, and therefore recourse is had to heat and pressure. The machines used for this occasion are hydraulic presses, but in their absence one similar to the annexed—Figs. 257, 258—is made to answer the same ends.

This press is composed of a stout frame, consisting of upright stanchions connected by cross-beams, the strength and firmness of which are in proportion to the pressure to which the materials are subjected; it works by a screw through a box in the upper cross-piece; and the former is moved by a lever introduced into holes in the shaft at its lower extremity. A trough, A, of convenient depth, and furnished with an outlet, B, to carry the expressed liquid to a recipient, E, rests on the lower cross-piece, and upon and within this is placed a wrought-iron cylinder, C, composed of two half cylinders united. These are perforated throughout, and furnished with strong hoops, *a*, which bind them at equidistant intervals, *b*. The top and bottom zones are narrow, and secured by a strong wrought-iron ring, adjusted at the back of the cylinder; this ring is formed of two parts working upon a hinge. Upon the front, a movable brooch, D—Fig. 257—bolts the half cylinders and hoops together, rendering them compact, and capable of resisting the pressure applied; after this is removed the pieces can be readily taken asunder by withdrawing the brooch.

Fig. 257.

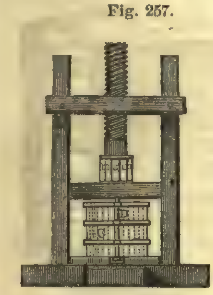
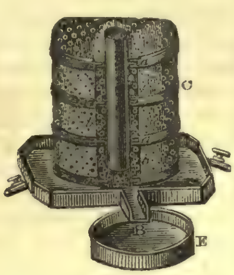


Fig. 258.



In working the press, the cracklings are introduced while warm, and then the power of the screw is exerted upon them as long as any fat exudes through the numerous perforations in the cylinder. To secure with greater certainty the removal of the whole of the fat, a modification of the press is adopted, by which the materials are maintained at a sufficiently high temperature to melt the fat. This consists in having a stout wrought-iron steam tube fastened to the trough in the centre of the cylinder; the upper end of the tube, which should reach about an inch above the cylinder, is hermetically sealed, and the lower end is connected to a pipe, conveying steam from an adjacent boiler. As the steam condenses, a pipe with stopcock carries off the water; the inlet for the steam should likewise have a stopcock to modulate the supply as convenient. In this way the heat, necessary to render the fat fluid, is maintained, while the press expels it into the trough, A, and thence, by the gutter, B, it is conducted to the reservoir placed beneath it. The pin, D, is unloosed when no more fat is expressed, and the residuary cake taken out, which is known as greaves, and is given as food to dogs and swine.

Great inconvenience attends this mode of rendering the fat, as well from the risk of its being carbonized, by which the good color of the whole charge would be more or less destroyed, as from the disagreeable and obnoxious vapors that are evolved during the melting; these are almost insupportable, so much so that it is not an unfrequent circumstance to have actions for nuisance, arising from this cause, laid against tallow-refiners. Such was the case with the Parisian tallow foundries a few years since, and this was the reason of a diligent inquiry being instituted, for the purpose of finding some means whereby the obnoxious evolutions could be repressed.

The first step taken was to conduct the vapors by a tube from a hermetically closed boiler to the fire, to be there consumed, by which it was supposed that the odor would be destroyed, and the saving of fuel arising from the heat produced by the ignition of the carbonaceous gases, was thought a matter of some advantage to the proprietors; but a little experience showed, first, that the solution of the fat was but imperfectly performed in this method of working, and also that there was always much danger to be apprehended from conflagration, which might result from the expulsion of the materials through the pipe into the fire.

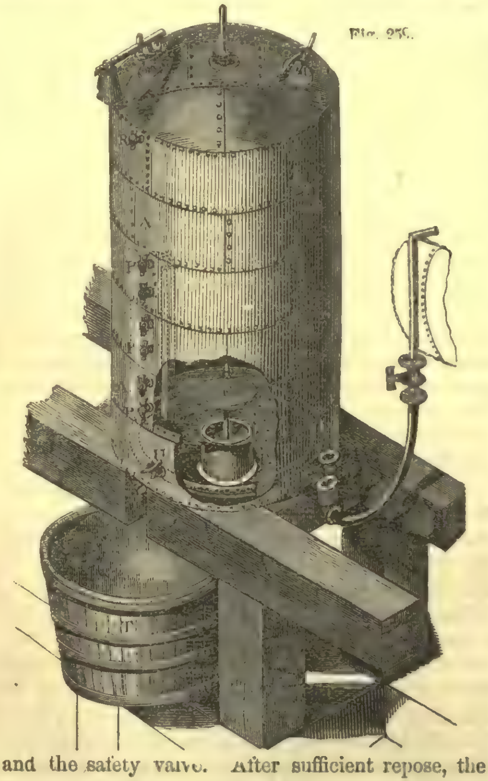
It was also found that the fats did not melt well when boiled with water only, but upon the addition of a portion of sulphuric acid the solution became more perfect, and the fat thus rendered was whiter and better than what had been purified in the usual way, but the greater portion of the disagreeable gases still continued to be evolved. The most appropriate quantity of the sulphuric acid and water for effecting the dissolution of the membranous textile retaining the fatty globules, was laid down by D'ARCET to be a pint and a quarter —seven hundred and fifty grammes—of water, and four ounces of sulphuric acid—one hundred and twenty-four grammes—to three pounds and a quarter of the minced rough tallow; but, in consequence of the foaming of such a mixture on the application of heat, it is requisite to have the boiler rather capacious.

Instead of passing the gases expelled from the tallow through the fire, it was deemed an improvement to convey them through a vessel of water, and arrest the condensible portions. This proved successful; the thick heavy smoke given off from the fire was thus prevented.

THIBAULT—who conducted the operation in an open vessel, and with about two hundred and fifty pounds of tallow, using water and sulphuric acid in the ratio before given—procured ninety-two per cent. of rendered fat, the waste being eight per cent.; but in a similar experiment in the ordinary way of procedure, the loss was found to be as high as fifteen per cent., and the time occupied in rendering the fat much longer. During the melting of the fat, the odor given off, though very disagreeable, was not nearly so rank as that proceeding from the caldron when the operation was conducted in the ordinary way; by the use, however, of a hermetically covered boiler, and a discharging pipe for carrying off the vapors to a refrigerator, this inconvenience is nullified.

Throughout America, the tallow and lard are usually rendered in the ordinary manner noticed at page 414, and this is productive of much annoyance and loss to the neighborhood and proprietor. The annexed Fig. 259, represents an apparatus invented by a partner of the firm of WILSON and Co. of Cincinnati, U.S., of which MORFIT speaks highly, as being most efficient for purifying rough tallows. In the establishment of this firm, there are three of them in operation; each is of sufficient capacity to hold from twelve to fifteen hundred gallons, and is composed of strong iron plates tightly riveted together; the form is that of a closed cylinder, the height of which is two and a half times greater than the diameter. The mode of working this apparatus, and the uses and applications of the various parts, will be mentioned in describing the process as practically carried out in the laboratory of the inventor. It is as follows:—The false bottom being arranged in its place, and the discharging hole closed up, the steam-tight iron tank or cylinder is filled through the man-hole with the rough tallow or lard material, to within about two and a half feet of the top. This done, the man plate, K, is securely fitted into the hole, H, and steam let on from an ordinary boiler, through the foot valve, into the perforated pipe, G, within the tank. Set the weight on the valve at the requisite pressure, and during the steaming, frequently and carefully essay as to the state of the contents of the tank by opening the test tap, R; if the quantity of condensed steam in the tank is too great, it will be indicated by the ejection of the fatty contents. In such case it is then requisite to open immediately the regulating cock, X, and draw off the condensed steam into the receiving tub, T, until the fatty matter ceases to run from the tap, R. After ten or fifteen hours' continued ebullition, the steam is cut off, and that excess already in, and uncondensed, allowed to escape through R and the safety valve. After sufficient repose, the fatty matter separates entirely from water and foreign admixture, and forms the upper stratum. It is drawn off through the cocks, P P, in the side of the tank, into coolers of ordinary construction. The tank being emptied of its lard or tallow contents, the cover, F, is raised by means of the rod, G, from the discharging hole, E, and the residual matters at the bottom let out into the tub, T. If, on inspection, the contents of this tub have retained anything of fat, it must be again returned to the tank, when they are being filled for a fresh operation.

Fig. 256.



According to the experience of the patentee in this matter, the pressure of the steam should be at least not less than fifty pounds to the square inch, to produce a good result, and the higher the pressure the more speedily and effectually will the smelting of the tallow take place. **Morfit** justly remarks, that a pressure beyond seventy or even sixty pounds to the square inch, however adapted it may be to the preparation of lard from the whole carcass of the hog, would be rather injurious to the production of good tallow; and, even in lard foundries, when the digestion of bones has been continued at such a temperature and pressure for some time, the substances are prone to decomposition; and hence he argues, that a moderate temperature and a slight prolongation of the time would, on the whole, afford better results. The marcs in the tub, T, are often mixed with other ingredients, such as peat or clay, and applied as a manure, which is said to rival the best guano. This apparatus is becoming very generally adopted in the American tallow districts,—a sufficient proof of its efficiency.

It often happens that the rendered tallow purchased by the chandler is very inferior in color, besides being more or less rancid, and, therefore, requires to be purified before manufacturing it into candles. Various processes have been tried at different periods for this purpose. WATT's patent, sealed in 1836, proposes to bleach and purify tallow by mixing with it sulphuric and nitric acids, as well as some bichromate of potassa and oxalic acid. When the fat is nearly melted in the steaming tub, the nitric acid is added in the ratio of one pound to a ton of tallow; but, before introducing it, it is diluted with one quart of water and two ounces of alcohol, naphtha, ether, or spirit of turpentine, the whole being then boiled for half an hour; after which the fat is washed, to free it from any particles of the materials employed in the purification. In this process, the materials taken seem to neutralize the effect of each other, for, whilst the bichromate of potassa and nitric acid supply oxygen for bleaching the fat, the oxalic acid and alcohol, or other liquor, divest these compounds, or the fat, of oxygen; however, the patentee alleges that the intended effects are produced to satisfaction.

Another patentee proposes to accomplish the same effect through the agency of atmospheric air at the melting degree of the fat, and proceeds to execute the operation by putting it into any convenient vessel, over which a hood connected with the chimney is fixed, for the purpose of conducting the effete vapors away from the workmen, and heating it by steam of greater or less pressure, from 170° to 230° Fahr. Streams of air are injected and forced through the molten material by means of perforated pipes placed at the bottom of the vessel, and a forcing apparatus to which they are connected. The length of time in which the air is being transmitted, varies with the degree of rancidity and discoloration of the body to be purified; and also with the nature of the fat in the vessel, when the apparatus is used to defecate any other kind of fatty bodies. Thus, a short period will suffice to dissipate the rank odor from tallow, and unless the color be very much impaired, the bleaching will be effected in ten to fifteen hours; but if substances, such as palm oil or the like, be subjected to this treatment, the time occupied will extend over twenty-five or more hours. In this process no combination apparently results, and the smell seems to be carried off mechanically, by the greatly extended surface exposed to the air passing through it at the above temperature, at which degree the nauseous matters are very volatile. The bleaching is performed by the oxygen of the air, which is abstracted by the oleaginous products in the stage of eremacausis, and from which the disagreeable odors emanate.

Some persons offer an improvement upon this plan, by adding carbonate of potassa to the melted fat, agitating it, and then allowing it to repose, for the double purpose of taking up water and the oleic constituents—the latter being the more prone to decompose—and when the whole has settled down, then transmitting the air through it as directed. But of all those modifications which have been announced by patents, and otherwise, the best is that proposed by WATSON, who, in his specification, sealed in 1842, directs the purification to be made by the hypermanganate of potassa, a compound often designated by the term *chameleon mineral.* The purifying element in this case, as in those processes already spoken of, is the oxygen taken up from the hypermanganic acid, which is reduced to sesquioxide of manganese; and the greater effects of the salt are due to the readiness with which it yields this element when it is decomposed by an acid. The work is executed by melting the fat in a leaden or wooden tank, and gradually mixing it with a solution, in which the hypermanganate is dissolved to the amount of about one-twentieth of the weight of the fat taken. When both are intimately mixed by brisk agitation, a quantity of dilute sulphuric acid, sufficient to communicate a slightly acid reaction, is added, in order to liberate the acid united with the alkali in the chameleon mineral; the whole is then briskly stirred for about an hour, during which time the temperature of the menstruum should be maintained at any point between 150° and 212° Fahr., as may seem desirable. The content of the tank is then allowed to rest, that the oily matters and the acid solution may separate, the former rising to the surface, from which it is drawn off into another vessel, and remelted in a fresh quantity of hot water and cooled, for the purpose of washing it. Steam is sometimes used to melt and raise the temperature of the fat in the tank, in which case the pipe ought to be supplied with a stopcock to turn it off when required. During the time the bleaching is being performed, samples may be taken from the bath of melted fat, and cooled, to observe if the proper degree of whiteness is attained; and if extra purified materials are to be produced, a fresh quantity of the chameleon mineral dissolved in water may be added.

THE WICK.—Having thus far described the nature of the animal fats, especially tallow, and the mode of preparing them for candles, it will be necessary, at this stage, to turn attention to the second essential requisite—namely, the wick—before proceeding to the general details of the manufacture. This is a subject which cannot be omitted; for, although it is true that the composition of a wick, so far as regards its formation from fibrous materials, does not strictly fall within the province of this work, still, in relation to the part it acts in the combustion and the evolution of light from the consumed materials, it becomes invested with peculiar interest even in a chemical point of view.

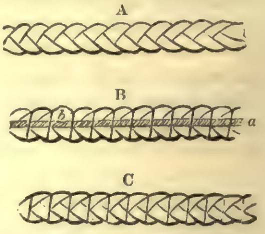
By the wick is meant the solid body, of whatever composition, which runs along the axis of the candle, and from which, upon being ignited, the light apparently issues. It is generally formed of fine threads of cotton twisted, or otherwise bound together; though occasionally flax fibre, and many other substances are employed: the former, however, answers best. The desirable qualities of wicks are, that they should be free from any tarry or albuminous matters, which, upon the application of heat, might fuse into hard carbonaceous excrescences, as is the case with hair, bristles, wool, silk, and other animal filaments; they should burn freely and completely, leaving a light ash, and this only in small quantities; they must be good absorbents, for the purpose of imbibing the melted fat in the bath which surrounds the ignited end during combustion. All these qualities are found in the greatest degree in cotton. In the form or construction of the wicks, some difference exists, according to the quality or composition of the candle; generally, they are composed of a number of threads, of greater or less fineness, twisted loosely or plaited together. It is important, and ought to be borne in mind, that no inequalities should exist, either in the shape of knots or adhering particles of cotton, or other substances, in any threads singly or collectively, but that they should be perfectly cylindrical throughout; candles with such inequalities in their wicks never fail to *gutter* when burned; in other words, when that part of the wick which bears the adhering or accumulated matter is burning, the sphere of heat, being more extended, reaches to the exterior walls of the cup surrounding it, and by melting these walls the liquid portion within them runs over; or the unevenness may form a coal, and fall off in a state of ignition on the tallow or other material beneath, and melt so much of it that it causes an overflow. These are disadvantages in candlemaking, which, though trifling in themselves, prove annoying to the consumers, and beget a bad name for the manufacturers; yet, with a little attention, they may be avoided. Again, the finer the threads composing the wicks, the more perfect will be the combustion of the illuminating medium, and the light produced will be far more resplendent than if the threads were coarse and bulky. This difference of the finer and coarser wicks bears upon a property of matter, known as *capillary attraction;* and as the solution of the phenomena under consideration requires an allusion to this subject, a short explanation of what capillary attraction is, will be here requisite.

It consists in the adhesion of certain liquids to certain solids at immeasurably small distances. If one end of a glass tube, of a very small bore, be dipped into water and held vertically, it will be observed that the liquid rises in the tube considerably above the level of that in the glass; and this will be greater as the interior diameter is less, though the ascent does not appear to increase in proportion to the calibre of the tube. In like manner, water poured into a wine glass appears to have a concave surface, in consequence of the liquid being raised at the sides by the adhesive affinity of the two bodies. Light bodies manifest greater power of capillary attraction than those which are dense; many evidences might be cited in proof of this, such as the rise of the sap and moisture in trees and other vegetals; the absorption of water by sugar, sponge, and many kinds of wood, when one part is put in contact with the liquid; the absorption of gaseous bodies by charcoal, *et cetera.* The ultimate cause of this affinity remains unexplained: men are acquainted only with the effect, but in the course of experiment it has been found that all substances do not attract each other like water and glass, or those other bodies mentioned; for instance, water will not adhere to a greasy or waxed surface, and mercury, if poured into a glass vessel, instead of presenting a concave surface as water would, appears convex, in consequence of the greater attraction of its exterior particles towards the centre, than that exerted by the glass upon them.

To conceive how, by this species of attraction, the molten substance of the candle ascends the wick, it is necessary only to regard the threads and the interstitial spaces between them as so many capillary tubes; and in the same manner as the water rises higher in those tubes of least calibre, so also will the liquid ascend to greater elevation in the wick that is composed of the finer threads, than in one of equal magnitude, but having the threads fewer and coarser. The result of this difference is, that the melted tallow is drawn up to a lesser distance by the wick composed of the larger threads, but in greater quantities than by the other, and that, when both are lighted, the former, in consequence of this behavior, brings more melted material into the flame than can be consumed; hence it is dissipated in the form of a thick heavy smoke; but in the latter, the threads become more thoroughly imbued, and the intermediate cells being smaller, there is not much fluid without the threads; therefore the combustion is more perfect, while the waste of material is less than in the former case. The fact is well known to the consumers of candles, that when the wicks are composed of fine threads, the light shed is more brilliant with less consumption of fat, and, therefore, the candles last longer, and require less snuffing, than if the threads were fewer and more bulky. The custom is, however, to make the ordinary sorts of candles with coarse wick, retaining the finer spun kind for stearin, spermaceti, or wax candles.

Many improvements have been lately effected in the construction of the wick, the principal point in view being the attainment of a method by which the necessity for snuffing it might be obviated. The first of these consisted in plaiting the wicks, which caused them, on being ignited, to untwist as they burned, and partially to turn out of the flame. By this contrivance, the combustion of the carbonaceous matter is perfected in contact with the oxygen of the air, and the candles require no snuffing. This plan was only applied to the finer kinds of stearin and spermaceti candles, until KEMPTON'S patent, sealed in 1842, pointed out another mode of making wicks, which, on being burned, required no cropping, and which might be employed in the formation of the commoner kinds: it consists in putting a cord or thread of fibrous material along the plaited wick, on that side where the strands run upwards from the centre to the edges, and then binding the cord thus laid, and the wick, with a fine thread. Fig. 260, annexed, shows a part of these wicks as they are prepared for use: A is a plaited wick, with the strand ascending from the centre at an angle to the edge; B is the same, with a view of the cord, *a*, both being bound together by the small thread *b;* and C is the other side of the wick, B, when ready for use. The object of this construction is to prevent the ignited end of the plait from turning too much out of the flame, so that, when bodies that are fusible at a comparatively low temperature are used to make the candle, the heat, which in that case would cause it to melt too quickly and thus to gutter, is averted, though, at the same time, the end of the wick turns out sufficiently for the complete combustion of the snuff. Where bodies with a comparatively high point of fusion are used in the candle, this running is not so frequent, and in such cases the string or cord may be of less bulk than when ordinary tallow is taken. It is necessary to have the twisted cord, which may be of hemp, yarn, or twine, on that side of the plait where the strands run upwardly and outwardly from its centre, because, during the combustion of the wick, the plait always turns to this side; and as the cord is stated to prevent a too great inclination, of course it will do this with greater effect by being laid on in this way at that side.

Fig. 260.



Others still further improve this method by impregnating the hard string with a paste made of nitrate of bismuth and oil, ground up together, or any such body which may cause the wick to turn out of the flame, and, at the same time, favor the combustion of the carbonized part so as to render snuffing unnecessary. Many construct the wicks by attaching to the plaits, by gimping, strings or threads of a different material, such as that mentioned above, and in doing so insert a wire in the centre, round which the threads or plaits are bound by the gimping apparatus; when this is done, the wire is withdrawn, leaving the middle of the wick loose, and better adapted for elevating the melted candle stuff during ignition. Some use the ordinary cotton thread twisted simply in a cylinder of a suitable diameter, instead of being plaited; but in that case the wick is dried, and soaked in a saline mixture, in order to cause the lighted end to protrude a little out of the flame. The solutions preferred are made by dissolving an ammoniacal or other alkaline borate or nitrate of bismuth, in a proper quantity of water; the cotton wicks have only to be steeped and dried when they are ready for use, and do not require snuffing.

To give a larger illuminating surface to the flame, many manufacturers use a double wick, plaited like that before mentioned, with the strands running from the centre upwards to the edges, and turning contrary ways, so that both ends will incline out at the point of combustion, and in doing so the extent of flame will be considerably enlarged, and, of course, the light increased. It has been recommended to dip the wicks in a solution consisting of three quarts of water, two ounces of borax, one ounce of chloride of potassium, one of nitrate of potassa, and one of chloride of ammonium, taking care that they should be thoroughly dried as well before as after the immersion. Plaited and gimped-plaited wicks are, however, used, and have all the advantages of requiring no snuffing, without the addition of any saline composition to cause the end of the wick to protrude from the flame.

Palmer is the patentee for this improvement, and his manner of procedure is to coil the prepared wick round a cylinder fitted for the operation, which is then immersed in a bath of melted tallow or wax, heated from 300° to 350° Fahr., and motion is communicated to it by a wheel; in this way the prepared wick is delivered at the opposite end with the same speed that it is supplied at the other. By this contrivance the wicks are completely dried and coated with the wax or tallow, and delivered from the machinery in a spiral form. When they are stretched and embodied in the material of the candle, nothing of the convolutions remains; but upon being ignited, and during the combustion, as the tallow or other stuff is melted down, the wick acquires the form given to it in the cylinder, sufficiently so to cause the end to turn out of the flame, and, therefore, obviate the need of snuffing, and, as the wick is thoroughly dried, the light given out is much improved.

Many other modifications of the methods above mentioned for preparing the wicks have been tried; but the differences are not important. As a general rule, the wick should always be made of such a size as to correspond with the fusibility and illuminating power of the fatty matter of the candle.

The labor of preparing the wicks in large factories is considerably lessened by the use of appropriate machinery. Besides the usual plaiting and gimping apparatus for making the improved kinds already alluded to, many others are necessary for cutting and otherwise preparing them for the mould or dipping frame. Fig. 261 represents a plan of a machine for cutting and suspending the wicks for *dip* candles, known as Sykes' patent, and Fig. 262 a sectional elevation of the same: A A is the frame; B a grooved roller, over which the cords of twisted or plaited cotton are passed from the bobbins, J J; C is the clip or holder, seen in a front elevation in the succeeding Fig. 263, and consists of two principal pieces or bars, *a* and *b*, held together by means of two sliding clamps, *c c*. D and E are the blades of the scissors; the former is fixed and the latter moveable. F is a trough wherein the wax, tallow, or other liquid fat which is used as a cement to retain the wicks upon the broach, is contained. The fat is kept liquid by means of a jacket, which is surrounded with hot water, steam, or heated air. H is a square rod or broach, upon which the wicks are fixed and supported during the time they are immersed in the frame that rests upon the table G.

Fig. 261.

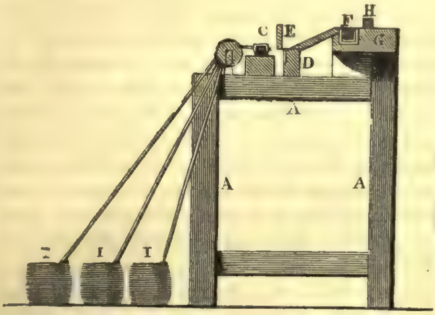
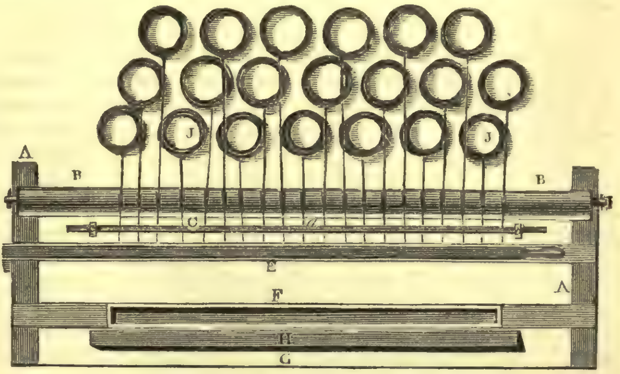


Fig. 262.



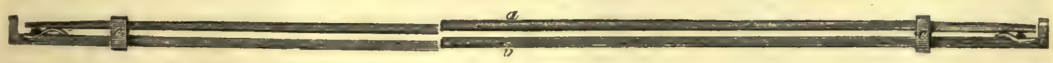


Fig. 263.

The following is the manner in which this apparatus is worked:—The cords being prepared in suitable bobbins are brought down through the roller, B, and secured between *a* and *b* of the clip or roller, C, each cord being left to project one inch in advance of the front edge of the clip. The bars, *a* and *b*, are made to lay firm hold of the cords by moving the clamps, *c c*, which bring them together in consequence of the wedge-shaped form of the upper bar, *a*. The cords being thus secured, the clip is lifted up and drawn forward by the workman, after which the free ends of the cotton that are left protruding from it are immersed in or brushed over with the oily cement contained in F, and then laid on the top side of the square broach or suspending rod, H, and are made to adhere to it with sufficient firmness to sustain them during the process of dipping by a slight pressure. Next, the clip is slackened by moving the clamps, C C, outwards; they are then pushed forth over the cotton towards the bobbins till the length to be cut for the candle is gained, when, by reversing the movement of the clamps, *c c*, the cords are again tightly laid hold on; and finally, the clip is rested upon the table, G, which is about one inch from the cutting apparatus. The movable blade, E, of the cutter is brought down, and the set of wicks of the proper length cut off, leaving as much of the cotton adhering to the end next the suspending rod as will support the next batch as before. The rod, H, with the wick adhering to it, is placed in a dipping frame, and another rod again loaded with wicks as before, and so on till the frame is full.

The bars of the clip, *c*, may be hinged, so that when opened they will allow the bundle of yarn or cotton to pass freely; but when closed they will take a firm hold of them, as shown in the cross section, Fig. 263.

Another machine, and one that is in extensive use with the American manufacturers, is the following, given by MORFIT, who states that it cuts, spreads, and twists as much wick in an hour, with the attendance of one man, as will suffice for a thousand pounds of candles.

Fig. 264.

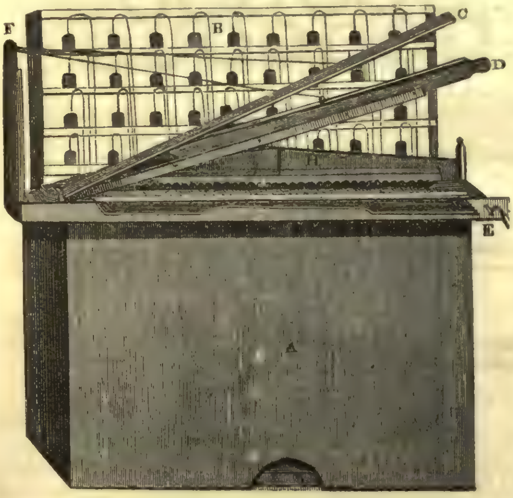


Fig. 264 is a drawing of the apparatus. A is the body of the machine, enclosing the pulleys and other appendages that regulate the movement of the carriage, B, which is set in operation by the treadle, G. The carriage, B, rests upon the body; it is a kind of framework running on wheels, and containing a number of boxes placed shelfwise, and serving as receptacles for balls of cotton wick, the ends of which run through a notched reed, below H; it comes forward upon the twisting board, E, at the back of which a knife, H, is fastened, that serves as the under blade of the clipper, D. This, when drawn down vertically, severs the wicks evenly. The twisting-box, E C, consists of two boards hinged, and moving on rollers. A turn of the crank near the end communicates that motion which twists the wicks after they have been cut by the knife, D, and this knife having effected its purpose is immediately drawn up by a counterpoise, F. At the front of the twisting-box, D, a sliding-box is so fixed that it can be graduated to regulate the required length of the wicks. Motion being communicated to the machine, the yarn is then cut, spread, and arranged on the rods simultaneously, and in complete readiness for dipping: as soon as the workman removes it, another rod rolls into its place, and thus the work proceeds till the wick or rods are worn out, when, as a matter of course, a fresh supply must be provided.

MANUFACTURE OF CANDLES.—Ordinary candles are made by two processes, called *dipping* and *moulding;* the former consists in immersing the prepared wicks repeatedly into a bath of the melted stuff, till sufficient matter has adhered to them, in which case the finished articles are called *dips;* and in the latter, the wicks are placed in moulds of some suitable material, and the melted fat poured in and allowed to cool; in this case they are termed *moulds*, or moulded candles. Besides these two methods others are resorted to, as in making wax candles, but of these more will be said under that head.

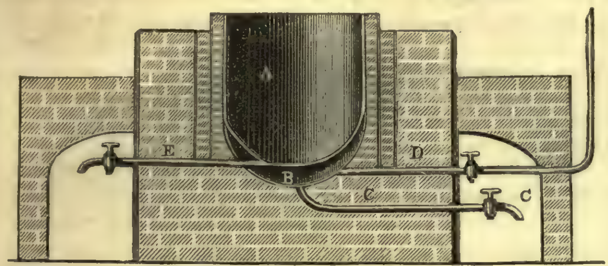
The requisites for chandlers who conduct a very large business are rather numerous and costly, particularly if they refine their own stock of materials; for then, besides the wick-making machines, and the usual apparatus for containing the oleaginous matters and supplying them to the wicks or moulds, rendering vessels, saponifiers, and presses are indispensable. Of these, some few have been already described, and as the several stages introduce themselves the others will claim attention.

In treating, in the first place, of dipped candles as being the most common, and perhaps the most extensively made, it may be desirable in this place to mention those articles which are required in the performance of the work, and to notice in due course the several improvements introduced of late years. Among those whose operations do not extend beyond the purchase of the purified tallow from the foundry, many will often find it necessary to submit this stock of purchased tallow to a second purification, especially if they desire to prepare a good and creditable article. For this purpose a copper caldron should be at hand, furnished with two or more stopcocks, one at the bottom and another at any convenient height—three to six inches—in the side, into which the tallow blocks are thrown, previously cut by a chopping-knife, similar to that already described, and as much water added as will cover the bottom of the copper to within a few inches of the upper outlet. Heat is then applied by a fire, which may be outside the walls of the shed or room, so as to keep any noxious vapors, from the melting tallow, and the waste heat from inconveniencing the workmen. The temperature applied should not exceed 212° Fahr., and indeed considerably lower than this will be found sufficient to melt the fat. As soon as the whole is liquefied, any solid impurities will either rise to the surface, whence they may be removed by skimming, or will fall to the bottom in the stratum of water, thus leaving the superior melted fat in a purer state.

Steam is employed by many in this part of the work, to secure the important point that none of the fat may be charred by happening to come into contact with the overheated metal of the boiler, an accident to which it is exposed in the preceding case, notwithstanding that the water is used as a preventive.

Such an apparatus as that alluded to is seen in the annexed engraving—Fig. 265—where A represents a copper tank enclosed in a jacket, B, soldered to it, and supported on brickwork or masonry. A stopcocked pipe, E, opens into the bottom of A, and two others, C and D, communicate with the interior of the lesser one at the bottom and side. Into the vacant space between the walls of the tanks, steam is injected from an adjacent boiler through the pipe, D, which is furnished with a stopcock for turning it off when desirable; the boiler is supplied with a safety-valve to ascertain what pressure of steam is upon it and on the chamber between the coppers. The fat, after being minced, is cast into the inner tank, with or without some water, and the whole is melted by the circulating steam; and when sufficiently fluid, it is drawn off through E, into another vessel, where it is left to repose, and when the solid matters form a sediment, the superior fat is drawn off into another tank, and the residuary matter expressed, and when this is done the copper is thoroughly cleaned before the next operation, unless the work be continuous; the condensed steam in the intermediate space may also be drawn off through the pipe, C. Instead of supplying a boiler for this purpose exclusively, it is evident that a pipe leading from any one on the premises will answer, and thus considerable expense be spared. A great many persons object to the use of water when melting the fat; they say that the two liquids intermingle, and that some of the former is eviscerated as the menstruum cools. If this were the case, the light emitted from a candle produced from such grease would be feeble. If the materials in the caldron, however, be allowed to rest for a proper period at a temperature of 150° to 160° Fahr. to maintain the fluidity of the tallow, no water remains; and by having the taps at the bottom properly set, and using only a small quantity of water at the beginning of each operation, none of it will be taken up by the fat. During the fusion of the suet, and while it remains hot, no cold water must be brought into contact with it, as they would repel one another with great violence, and, consequently, some of the fat would be ejected.

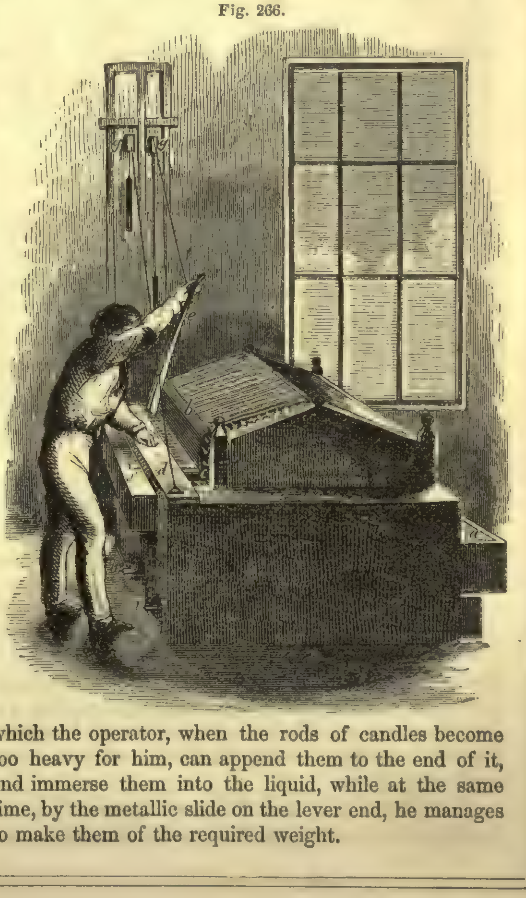
Fig. 265.



After the fat has been drawn off, comparatively purified by the process described, it is conducted to the candlemaking department, and mixed with beef and mutton tallow in equal proportions, to prevent any brittleness in the candles. The bath containing the material, in moderate-sized factories, is an oblong vessel, made of stout boards firmly put together, and resting on a pedestal or other support two feet high; this trough, which should be sufficiently deep for the immersion of the largest-sized candle made in this way, is lined with lead, and on the side on which the operator stands a thick board of beech or other wood, and of the length of the recipient, is fixed in a slanting position, the use of which is to detach the superfluous material from the end of the candle after its first immersion.

Beside this trough, and to the left of the workman, is the reservoir of melted fat—*c c*, Fig. 267—kept properly fluid by a jacket containing steam or hot water; or the same may be effected by a renewal of hot liquid matter from the purifying caldron at regular intervals. On the right hand is fixed a long upright side frame, under which is a kind of tray, made of boards, and lined or unlined with lead; this is of the same size as the frame, and its sides incline outwardly, but in an upward direction: it is intended to collect the droppings which fall from the wicks on their removal from the bath after the first immersion. Above this apparatus is a beam, by which the operator, when the rods of candles become too heavy for him, can append them to the end of it, and immerse them into the liquid, while at the same time, by the metallic slide on the lever end, he manages to make them of the required weight.

Fig. 266.



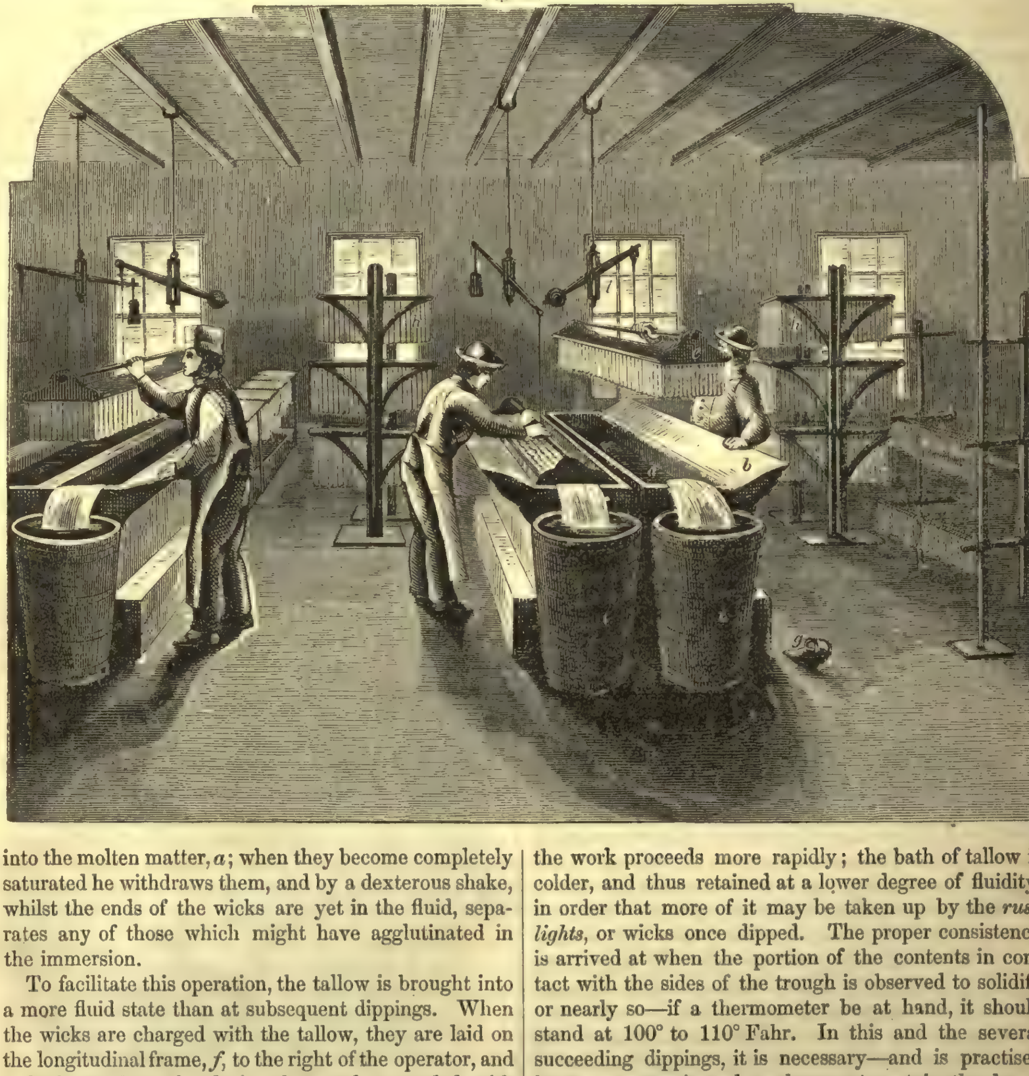
Such is the arrangement at a very compact manufactory in Liverpool, where the candles are dipped by hand, though with considerable expedition, as six or eight rods, each of which holds ten wicks, are immersed at once.

Fig. 266 shows the machine for cutting the wicks; *a* is the box where the balls of cotton are placed. The ends of the wicks are drawn over the bridge, *b*, of the machine, above which the rods, *c c*, are introduced, and as the workman fills each rod he brings the others forward by means of the treadles, *h i*; *d* is the hand-board which keeps the wicks in their place, while they are being cut by the knife, *e*. Both the knife and board are lifted up, after the wicks are cut, by counterpoises, *g g*, attached to them by cords passing over small pulleys. The length of the wick is regulated by the screw, *f*, in front of the workman.

The method pursued to load the rods, or *baguettes*, as they are called, with the wicks, is equally expeditious and easy.

Having all the rods supplied with wicks, they are brought to the frame at the back of the trough, and the dipper takes six or eight of these at a time upon the small frame, *e*, which he holds in his hand, shown in the annexed Fig. 267, and by an expert method, which can only be acquired by practice, introduces the dried wicks into the molten matter, *a*; when they become completely saturated he withdraws them, and by a dexterous shake, whilst the ends of the wicks are yet in the fluid, separates any of those which might have agglutinated in the immersion.

Fig. 267.

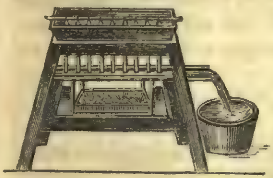


To facilitate this operation, the tallow is brought into a more fluid state than at subsequent dippings. When the wicks are charged with the tallow, they are laid on the longitudinal frame, *f*, to the right of the operator, and a fresh number of rods is taken and proceeded with in the same way, till the whole of the wicks are immersed, keeping the bath filled with the fluid matter during the time.

The second dipping is now commenced, and is performed in the same way as the preceding, except that the work proceeds more rapidly; the bath of tallow is colder, and thus retained at a lower degree of fluidity, in order that more of it may be taken up by the *rush lights*, or wicks once dipped. The proper consistency is arrived at when the portion of the contents in contact with the sides of the trough is observed to solidify or nearly so—if a thermometer be at hand, it should stand at 100° to 110° Fahr. In this and the several succeeding dippings, it is necessary—and is practised by every experienced workman—to retain the lower part of the candle a little longer in the melted tallow than the other, to remove the accumulated matter which is found upon the under extremity, in consequence of its descent from the upper whilst the tallow remains fluid; and also the ends of the small candles should be tapped upon the board, *b*, in front, on their withdrawal from the bath, to detach the small pellicle that drops down, but which solidifies before it falls. After several such dippings the candles become sufficiently large, and towards the end the frame, which hitherto was held in the hand, is hooked upon the beam, *d*, and the exact weight given. The final dippings must be performed with care and skill, to communicate a proper cylindrical smooth appearance. To insure this, the bath is kept at a higher temperature, if there is an overweight, for the purpose of removing it, and almost invariably it is a little elevated to give an even exterior to the article. If the ordinary precaution of tapping the ends of the candles on the board, as they are raised each time out of the trough, be neglected, or only imperfectly executed, their extremities will extend half an inch or more below those of the wicks, and the matter thus accumulated becomes a waste to the consumer, and might eventually do serious injury to the manufacturer. Should this be the case, as a matter of economy both to the maker and consumer, this adhering matter ought to be removed; and although it may not be of such frequent occurrence as to warrant the use of a separate machine, yet it may not be altogether out of place to describe one.

Fig. 268 is one which answers well: it consists of a stout frame of moderate height, on the top of which a kind of bottomless trough or box is placed, across which the broaches or rods are laid, so that the candles hang down within its sides. A sheet-iron tray, with raised edges, inclining a little to one end, and terminating in a spout, is made to touch the candles by adjusting pins, that may be inserted in holes in the side frame; and beneath this a small sheet-iron portable furnace, containing some red hot coals, is supported; the heat from this part of the apparatus acting upon the tray, melts the ends of the candles to the proper length, while the material flows out by the spout, and is collected in a vessel placed under it for this purpose.

Fig. 268.

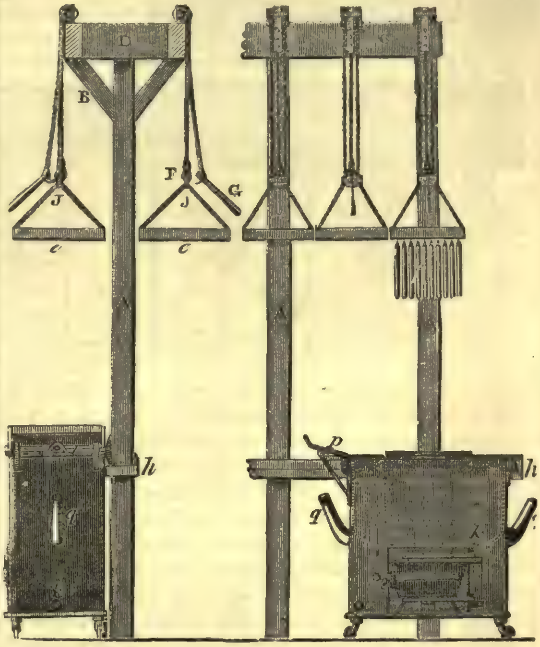


Finally, if highly improved candles are to be made, they are completed by passing them through a board, in which are perforations of a size suited to the body of the candle. On one side of the board the hole is cut away till it comes to nearly a sharp edge at the other, and which, by acting upon any protuberance in the body of the articles, makes them look in a manner like moulds. It seems, however, that this process would occupy too much time, and from the facility with which moulded candles are now made, it would be preferable to cast these kinds at once.

This process completes the operation of dipped candles on a small scale; in consequence, however, of the impetus given to manufactures in general during the last twenty years, considerable improvements have been effected in this branch, which, though not of a chemical nature, and, therefore, not requiring to be dwelt upon at any length in this work, yet, considering how much a mechanical invention may, and often does, suggest to the operator, it is the Editor's opinion that, to the chandler as well as the general reader, a brief description of a few of these cannot be uninteresting.

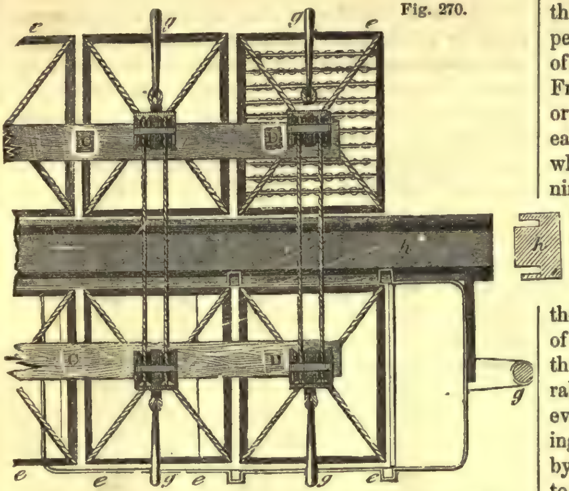
Fig. 269 is a front view of an improved form of apparatus, by which many candles are dipped in succession with comparative ease and regularity. The following is MORFIT'S description of this instrument:—The frame consists of five oak-wood beams, A, each bearing near its top two abutments, B—seen in the end view, Fig. 269—connected together by the long cross pieces of horizontal frame, C, throughout the length of which are five small traverses, wherein the beams or posts, A, of the frame are mortised. The iron caps, D, are fixed upon the sides of the long cross pieces of the frame, C, and each has two brass pulleys. The fastening or connection of these caps is effected by stout screws inserted in the beam, C. Each pulley receives a cord, F, at the extremity of which is a small wooden frame of a rectangular form, and grooved at the sides interiorly, for the purpose of supporting the broaches or rods on which the wicks are suspended. The wooden handles, G, have each a hook fastened in a hole in the centre of a small rectangular iron-plate, J, to which are attached the cords of the pulley, and rectangular frame, *e*. The long traverse, or cross piece, *h*, is grooved on each side, to facilitate the movement of the furnace. This arrangement of the pulleys, and the grooving of the beam, *h*, are shown in the vertical view—Fig. 270—where the arm of the furnace fits into the grooving, along which it runs as the latter is pushed round the machine. The furnace moves on four castors. It has two doors for the purpose of introducing a small tray, wherein the red-hot coals are retained, the heat from which is necessary to preserve the baths of tallow and mutton

Fig. 269.



suet above it, at that degree of temperature most conducive to the ready formation of the candles by dipping. There are two baths, one inserted in the other. The larger is generally kept at a temperature of 85° to 95° Fahr., and by contact of the liquid heated to this degree, the smaller bath of material will have acquired a temperature of 50° to 60° Fahr., and by this means the adhesion of the stuff is expedited. That no part whatever may drop off from the candles, on being made to emerge from the bath, and be lost, a plate is fixed to the exterior of the tank, and inclining inwards, so that any of the fat that may fall upon this plate is returned to the bath without waste. To cause the combustion of the coals in the enclosed furnace, air is admitted through two openings, which, however, may be closed at will. Crotchets, in the groove of the cross piece, *h*, serve to conduct the furnace from one frame of candles to another. When this machine is worked, the two receptacles for the tallow and suet are filled with these bodies properly mixed, and then heated to the degree above-mentioned by the fire beneath them. Next, the furnace is pushed forward under the frame, *e*, whereon the rods, loaded with the wicks, are supported; this frame is depressed by the hand, and the wicks immersed repeatedly in the fat till the candles have become sufficiently large, and then the frame is raised to a higher elevation, and so retained by hooking the handle, G, to the plate, J, as before described.

Fig. 270.

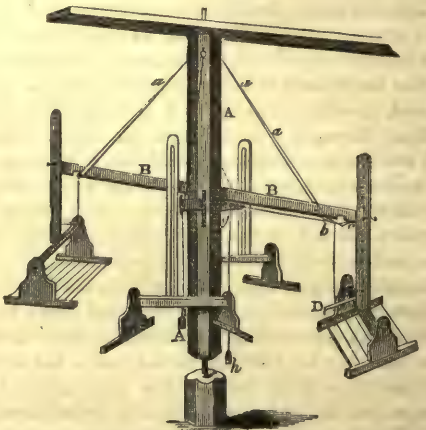


The furnace is then removed to the next frame, and the dipping proceeded with, as in the forementioned instance; and so on till the frames are worked off.

Many similar machines are employed by chandlers, and considered very advantageous; but as a description of them would occupy too much space, and as they work on principles analogous to those just mentioned, they are passed without further notice. There is one, however, which, on [illegible] of its reputed convenience and its adaptation to candle-dipping on a large scale, will be here described.

Fig. 271 shows the machine as it stands in the middle of the dipping-room. A A is a strong upright post turning upon iron axes, which are inserted into sockets at the top and bottom. Near its middle, six mortises are cut, at small distances from one another, into each of which is inserted a long bar of wood, B B, which moves vertically upon an iron pin, also passing through the middle of the shaft. The whole presents the appearance of a large horizontal wheel with twelve arms, of which, however, only two are seen in the figure. From the extremity of each arm is suspended a frame, or *port*, as the workmen call it, containing six rods, on each of which are hung eighteen wicks, making the whole number upon the wheel twelve hundred and ninety-six. The machine, though apparently heavy, turns round by the smallest effort of the workman, and each port as it comes in succession over the dipping mould is gently pressed downwards, by which the wicks are regularly immersed in the melted tallow. As the arms of the levers are all of the same length, and as each is loaded with nearly the same weight, it is obvious that they will all naturally assume a horizontal position. In order, however, to prevent any oscillation in the machine in turning round, the levers are kept in a horizontal position by means of small chains, *a a*, one end of which is fixed to the end of the top of the upright shaft, and the other terminates in a small square piece of wood, *b*, which exactly fills the notch, *c*, in the lever. As one end of the levers must be depressed at each dip, the square piece of wood is thrown out of the notch by the workman pressing down the handle, D, which communicates with a small lever inserted into a groove in the bar, B. In order that the square piece of wood fixed in the extremity of the chain may recover its position upon the workman's raising the port, a small cord is attached to it, which passes over a pulley inserted in a groove near *c*, and communicates with another pulley and weight, which draws it forward to the notch. In this way, the operation of dipping may be conducted by a single workman with perfect ease and regularity, and even despatch.

Fig. 271.



No time is lost, and no unnecessary labor is expended in removing the ports after each dip; and, besides, the process of cooling is much accelerated by the candles being kept in constant motion through the air. The number of revolutions which the wheel must make in order to complete one operation, must obviously depend upon the state of the weather and the size of the candles; but it is said that, in moderately cold weather, not more than two hours are necessary for a single person to finish one wheel of candles of a common size. Upon the supposition, therefore, that six wheels are completed in one day, no less a number than seven thousand seven hundred and seventy-six candles will be manufactured in that space of time by one workman.

Of those improvements offered to the public under the seal of the patent office, the best is that of Mr. **Palmer**, who professes to manufacture dipped candles, the wicks of which will turn out of the flame during their combustion, and will, consequently, not require snuffing. Such has long been effected in spermaceti and other candles made of hard materials, fusible only at elevated temperatures; but the low degree at which tallow candles melt, was found to render them incapable of this adaptation. The wicks in the better quality of candles, as previously stated, were made of cotton threads, plaited in three strands, and in their combustion inclining to that side where the latter run from the centre upwards to the verge. Although it might appear that the arrangement which applies to sperm would equally apply to tallow candles, experiment proves the contrary. To account for this, the first point appears to be, that the wicks which serve to throw sufficient light from a sperm or a wax candle, would not consume enough tallow to emit the required degree of light from candles of that material; and, secondly, during the burning of the tallow, the fine threads entering into the composition of the wick get so overloaded with the fat, that they fall, and cause the candle to gutter or run. **Palmer's** remedy for this difficulty is, to bind two plaited wicks together by a string of cotton or yarn, in such a way that the strands of both will run in the same direction, and, therefore, cause them to turn out of the flame together. Strength is thus given to the wick to support itself, and further, the latter is sufficiently large to give out a medium light, such as tallow candles emit. In this case it seems that the plaiting to some extent checks the attraction, and thus the part of the wick above the body of the candle is not overburdened, though containing sufficient matter to produce by its consumption a good light.

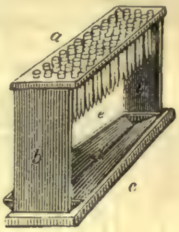
Others use, instead of a double-plaited wick, bound or gimped together, a single plait made of three strands in the usual way, only that the threads are much coarser than those forming the wicks of the finer candles. In this case also, the wick has sufficient body and does not flag. Whether some of these improvements are of real worth, it remains for the public to decide.

Mould Candles.—Having treated of dipped, the attention of the reader must now be directed to moulded candles—a branch of the business which has become much more extensive than the other, particularly during the last few years.

The labor of making mould candles is considerably less than is required for dips, while the time occupied is shortened in a much more marked degree; for, instead of the repeated operations required for the latter, the moulded candles are formed at once, by casting them in their appropriate shape.

It was formerly the practice, and it still continues to a limited extent, to have the moulds arranged in a frame made of four solid pieces of hardwood; the top one is often an iron plate, perforated with holes corresponding to the size of the moulds, and bordered round by a rod of the same material. The lower part of the frame is occupied by a small movable tray, or trough, for catching any of the tallow that may drop from the moulds. This arrangement is represented in Fig. 272, where *a* shows the upper slab, *b b* the sides, *c* the base, and *d* the trough for securing any fat that might fall through the moulds, which are represented by *e*. In this case the wicks are always inserted by the hand—a process which, even to a practised workman, occupies a great deal of time. After the wicks are properly adjusted, the tallow is poured into each mould singly from a can, something like a watering-pot from which the rose is removed, or it may be poured upon the board, and then the whole of the moulds are filled at the same time. In the latter instance, the rim around the top prevents any of the tallow flowing over. The frame is then either left at rest, or removed to a part of the room where it remains exposed to a current of air, till the melted fat solidifies and hardens, after which the candles are drawn out.

Fig. 272.



Moulds of the shape of the annexed figures are the sort usually employed in this part of the business. The body, *a a*, is proportioned to the size of the candle which may be called for in the market, and is slightly conical. Its lower end is shaped so as to form the top of the candle; it is perforated in the centre, in order that the wick should pass through, and the upper part or base has a narrow flange, which supports it upon the top part of the frame; this flange has a screw-thread cut upon it, in order to adjust it more firmly. French moulds are composed of two parts, the cylinder and top piece; the latter is technically called *culot*, and is seen in Fig. 273, and the wire for hocking on the wick, to preserve it in the centre, is shown fixed to the interior of the culot. Fig. 274 is a front view, and Fig. 275 a section of the same, showing the manner in which the funnel part, or culot, fits the enlarged space in the cylinder, and also the position of the wick suspended from the wire hook, which should be exactly in the centre of the mould, otherwise the wick will not have a uniform coating of tallow upon it; and the inequality arising from this circumstance, in the burning of the candles, will be

Fig. 273.

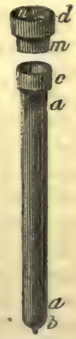


Fig. 274.

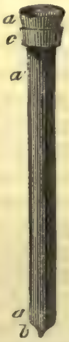


Fig. 275.

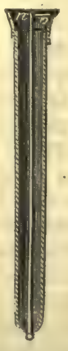
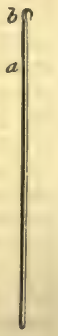


Fig. 276.

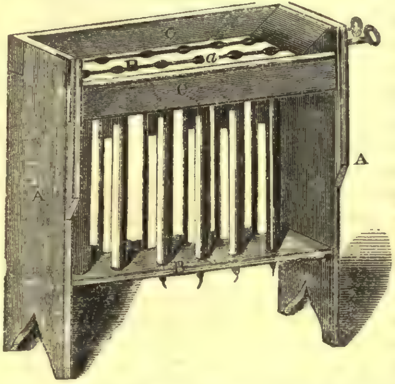


injurious, inasmuch as it will cause a guttering. The conical shape of the cylindrical part of the mould is necessary to facilitate the drawing of the candles, as without it much inconvenience and difficulty would be experienced in performing this part of the business.

The American manufacturers employ, on a small scale, an arrangement of moulds, as seen in the cut, Fig. 277. It is very similar to that shown in Fig. 272, only that the wicks are supported by a series of horizontal wires that are passed along through the loops of the wicks; they differ from the French moulds in having no culots.

The subjoined sketch of this arrangement is taken from Morfit, who describes it as follows:—A A are the two upright ends of wood which support the two cross beds, B B, that serve to hold the mould in an upright position. The upper bed is of metal, this material being better than wood, to which the redundant tallow sometimes adheres so tenaciously as to cause a delay in its removal. C C are the broad side pieces, which, with the upper ends of the uprights, form a receptacle for the melted tallow when the moulds are being filled. One of these side pieces slides on a groove, so that it can be moved downwards to afford facility, firstly, in threading the moulds with wicks, and secondly, in removing with a knife the excess of tallow which congeals upon the metallic tray. The wires which traverse the upper bed of the stand, immediately over the mouths of the moulds, for the purpose of suspending the wicks, are seen at *a*. Each stand is of a convenient size; and from the conveniency of the whole arrangement, it is well worth the additional cost as compared with the commoner stands of moulds.

Fig. 277.



When such moulds as those represented in the preceding figure, or in Fig. 272, are employed, the manner of wicking them is as follows:—A strong wire needle, bent into a catch or hook at one end, and turned into a ring at the other, for facility in handling it, and similar to Fig. 276, is employed for this purpose. The operator lays the frame horizontally on a table, and taking a number of the prepared wicks in his left hand, he inserts, with the right, the small hooked end of the wire at the lower end of each mould, and as soon as it appears at the mouth the looped end of the wick is laid hold of, and by withdrawing the wire the wick is carried through. The wick, at the mouth of the cylinder, is secured by passing a wire through the loops over each range of moulds. When the whole batch is in this way completed, the frame is restored to its original position, the wicks being first stretched tightly, and fastened by means of a small spigot, or wooden plug, introduced at the lower part.

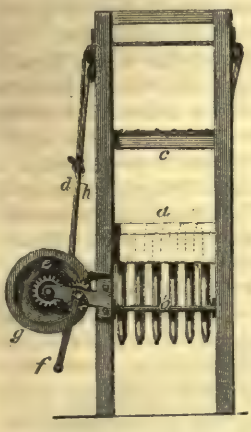
The next operation is the filling of the moulds, and this is performed by pouring in the melted tallow till all of them in the stand or frame are filled, after which they are left at rest till the drawing time.

The moulds used for the manufacture of tallow candles are composed of iron, brass, and pewter. The first substance is rarely employed; the next of these is too readily acted upon by the acidity which is liable to prevail in the tallow, and which would destroy the moulds made of it; therefore, pewter is found the most applicable. For stearic candles, instead of pewter, which is an alloy of lead and tin, a mixture of tin and antimony is taken, partly on account of the smutty color communicated to the candles, and partly because of the difficulty experienced in drawing them out, when moulds of lead and tin are used; both inconveniences are said to disappear when the cylinders are composed of tin and antimony. Many chandlers, however, employ a proportionate quantity of lead without any injurious effects being discerned. In choosing moulds, preference should be given to those that are hard and well burnished interiorly. Care also should be taken that the burnishing is effected by a vertical motion, instead of a rotatory one; for then the number of imperfections observed in the candle, and which are owing to the inequalities or circles in the mould, will be guarded against. Further, another useful quality in the mould, and one which considerably expedites the process of candlemaking, is its thinness; but this, of course, should not exclude it from having sufficient hardness and tension to bear the ordinary effects of the wear and tear consequent on the manufacture. When the moulds are thin, the liquid tallow solidifies much quicker than when a large mass of metal surrounds it. These moulds should be at hand in sufficient numbers, as well as in all the variety necessary for making every size of candles found in the market. Recently, glass moulds have been employed with advantage, and to prevent breakages they are protected by a casing of caoutchouc.

In the view already given, the facture, if conducted within these limits, would indeed be very inadequate to the demand for this article; in fact, the requisition could never be answered, were the same tediousness to pervade the process. Many contrivances have, therefore, been attempted to supply candles with greater speed, while, at the same time, the quality might be rather improved than injured. Many of these, which the Editor considers the most important, will be noticed in the succeeding pages.

The annexed—Fig. 278—is an end view of a machine, which is said to be capable of turning out six hundred candles in half an hour by the aid of one workman. This machine has the form of a six-footed table, seven feet in height, and divided into three compartments. Its upper surface, or top, consists of a hard wooden board, *a*, of fifteen lines in thickness, and pierced with six hundred circular holes, in which the moulds are placed and fastened by two screws which they carry about five lines above their grand opening. At a distance of eight inches below this, a second board, *b*, is fixed and perforated as the preceding, and in these holes a part of each mould sets, in order to keep them in a vertical position. Finally, the third board, *c*, contains as many funnels as there are holes in the boards, *a* and *b*—a funnel answering to each mould. The top surface of this board is divided off into four equal parts by the iron frames, bearing the iron rods upon which the wicks are strung; the latter being inserted into the frames at the same time. Into these frames, by means of a funnel for that purpose, is poured the quantity of sebaceous matter necessary to fill the number of moulds placed thereunder. When the tallow has congealed sufficiently, the candles are drawn by raising the board, *c*; this is done by the aid of six iron jack-screws, *e*, eighteen inches in height, and fastened to the six legs of the frame at their upper extremities.

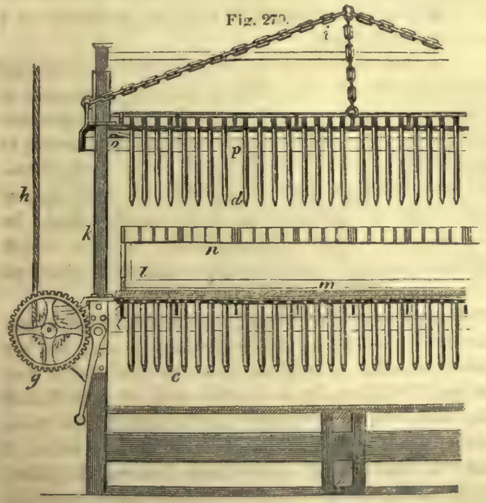
Fig. 278.



These screws are propelled by turning the winch, *f*, which reacts upon the wheel, *g*, and this again, by moving one of the wheels of the jack-screws, winds the cord, *h*, and lifts the board, *c*; the candles are thus drawn from the moulds and hang in the air, but are severed at one effort from this plate by a large knife. During the time that the workman is cutting the candles from the top plate, *c*, *a* is covered, in order to protect the moulds from the falling particles of tallow and any other matters.

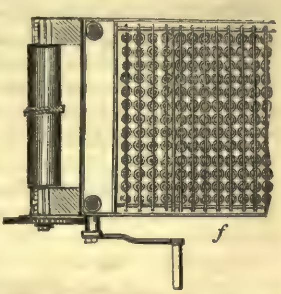
Fig. 279 is a front view, and Fig. 280 a plan, of a similar machine, much improved. Figs. 281 and 282 are plans of the plates *a* and *b*, Figs. 283 and 284.

Fig. 279.



Both these plates or tables are pierced with holes; those of the lower receive the moulds, *c*, and those of the upper, the culots, *d*, which, penetrating the orifice of the moulds, prevent, during the casting of the candles, the overflow or spilling of the suet upon the under table. The moulds are caught and lodged in the lower table by iron hooks, *e*—Fig. 284—fastened by screws, the cleft heads of which are seen in Fig. 283. There is a space left between the table and the hooks, in order that, when the candle is being drawn, the mould, as soon as detached therefrom, may fall by its own weight, and allow the candle to escape without resistance. The wicks are strung upon iron wires, or rods, *f*—Fig. 280—laid level upon the upper table, and notched at regular distances to indicate the proper position for the wick.

Fig. 280.



Each wick is furnished with an iron needle, and in this way as many moulds as are in one line can be wicked with facility at once. The drawing is effected by means of a windlass, or winch, *g*, fastened to the foot of the machine, and upon which runs a cord, *h*; the latter passes upon the pulleys, and is attached to a chain, *i*, fixed to the centre and each of the four corners of the upper table. To avoid the oscillating motion of the lower table, there are adjusted four iron columns, *k*, which pass into or through four copper clamps fixed upon the upper table. The cutting of the candles is accomplished by raising the upper table, so that a wooden frame, *l*, resting upon a plane, *m*, of the same material can be placed beneath it; this is partly to protect the moulds under *m* from any casual dirt, and also to retain the candles during the cutting; for, when the frame is properly set, and the upper table lowered, each candle drops into a square, *n*, formed of tape, and hence there is no fear of their being bruised or broken by the fall. The knife, *o*—Fig. 279—which is used for this operation, slides upon two iron strips, *p*, placed at a proper height, and is removed after performing its work.

Fig. 281.

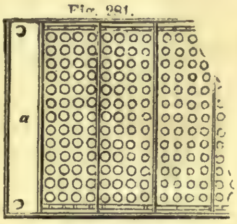


Fig. 282.

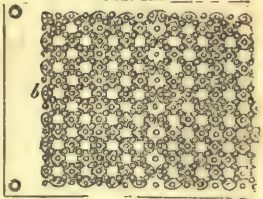
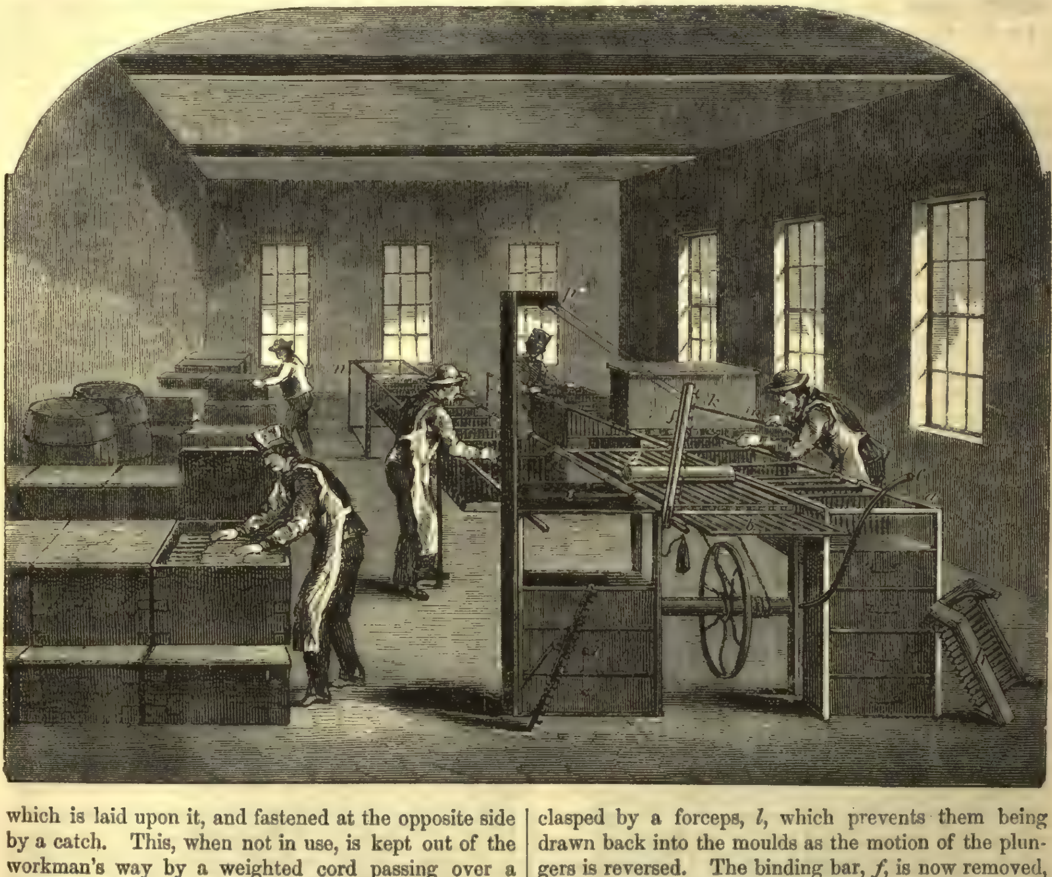


Fig. 283.

Fig. 284.

In England, the machine generally adopted is that known as *Morgan's*, and represented in Fig. 285. It includes a drawing apparatus, moulds, and other appurtenances, necessary to render it continuous in its operations. Eighteen moulds are arranged in each of a number of frames, similar to that indicated by *h*; to the latter, circular boxes are appended, containing eighteen reels, each carrying sixty yards of wick, from which the former are supplied. The moulds are composed of two parts: one a conical cylinder of the usual shape, and the other the heel, forming the top of the candle, and in which an orifice is made for the passage of the wick. At its end is a round ball, which fits into a copper tube or *plunger*, which can be forced through the cylindrical part, for the purpose of expelling the candle and wicking for the next one. Supposing the moulds to be already wicked, the frames are conducted along two parallel bars, *a*, similar to a line of railway, to the filling machine, *k*. This is a box containing the liquid material, and furnished with a thermometer to denote the temperature. There is a number of outlets corresponding to that of the moulds in the frame, in the under part, which are closed by plugs or valves in connection with the lever, *m*. The workman pressing upon *m* lifts the valves, and the material flows out into the moulds till filled; the frame is then pushed on, and another brought under to be replenished. An attendant beyond the filling box, as soon as the matter solidifies, removes the forceps which hitherto held the ends of the wicks, also any excess which may have run out into the top of the frames, and then pushes them along to the end of the line, where, by means of a carriage, *n*, moving on rails, they are conveyed to other parallel lines like the foregoing, that bring them to the drawing department. During this passage the candles are perfectly solidified. As soon as the frames arrive at the machine, the operator places each in succession horizontally upon the metallic plate, *o*, by raising the latter—and with it the frame—from its inclined or vertical position to that indicated in the figure, by the handle attached to it. The frame is now moved on to the plate of the drawing machine, as represented, and there secured by a bar, *f*, which is laid upon it, and fastened at the opposite side by a catch. This, when not in use, is kept out of the workman's way by a weighted cord passing over a pulley, *p*. The handle, *c*, of the winch is pushed outwards, and this forces the plungers, *d*, forward; when laying hold of the heel of each mould, the power being still exerted, the candles are displaced, and thrown out upon the board, *b*, where they are held by a contrivance in some respects similar to *f*, whilst they are being cut by a circular knife or scissors from the string of wick. When this is done, the catch is loosened, the eighteen candles deposited in a box, and the end of the wicks clasped by a forceps, *l*, which prevents them being drawn back into the moulds as the motion of the plungers is reversed. The binding bar, *f*, is now removed, and the frame taken by an attendant to the parallels, *a*, and pushed on to be refilled. In this manner, the operation of continuous moulding is carried on, and when the wicks on the reels are expended, the latter are replenished, and the process renewed.

Fig. 285.



Many other machines for moulding candles are in use, but those which have been given may suffice as illustrating the latest improvements; and from these the intelligent manufacturer may learn as much as will enable him to make judicious alterations with decided advantage to his business.

Regarding the material for tallow mould candles, a few further suggestions might be offered, in addition to what has been previously stated—suggestions having reference chiefly to the two principal qualities that enhance, in public estimation, the value of the product, namely, *whiteness* and *hardness*. Candles possessed of these two requirements, furnished with proper wicks, and otherwise well made, always command a better sale than those of a yellowish hue, having no marked degree of hardness beyond that of ordinary tallow. One mode of obtaining this end is, to remove the olein of the fat, by pressure and saponification with lime, or some other alkaline body; but an examination of the materials in those candles which possess considerable hardness, as well as beauty of color, will prove that the above is not the means adopted to give them their marked qualities. Alum, cream of tartar—bitartrate of potassa—borax, nitre, and many other similar salts, added to the tallow during fusion, or to the water which may be employed to protect it from the bottom of the copper, serve to stiffen and clarify the fat very much. MORFIT, who made experiments on this subject, states that cream of tartar, mixed with a fourth of its weight of calcined borax, afforded the most satisfactory results. The powdered salts were sifted over the surface of the melted fat, using variable quantities, from one to two ounces per pound of fat. The borax causes the solution of the bitartrate in the water employed to protect the tallow from contact with the bottom of the vessel.

In Germany, the annexed method is generally practised to accomplish the same end:—Twenty-four pounds weight of suet, coarsely minced, are placed in a caldron of boiling water, and as the water evaporates the original quantity is kept up by fresh additions; after an hour or so, the content of the kettle is strained through a clean cloth, and then the suet is heated for half an hour with two pints of water, in which one ounce and a half of alum, two ounces of purified carbonate of potassa, and eight ounces of common salt, have been dissolved. The whole being again strained, the same quantity of water is added, together with half an ounce of saltpetre, half an ounce of chloride of ammonium, and one ounce of alum; the three compounds being finely powdered together, and the menstruum gently boiled till bubbles cease to rise, the surface becomes smooth, and the central part appears transparent, and after this point is attained, the fire is withdrawn. All the impurities will be found precipitated to the bottom of the blocks of tallow when taken from the caldron, and may be removed by scraping off these portions; but, to purify it the more, these blocks are submitted to another fusion, with the addition of two drachms of saltpetre—nitrate of potassa—finely powdered, observing to skim any extraneous matters that may rise to the surface during the boiling. After this operation, the clear tallow is drawn off into appropriate tubs to cool. The candles made from the material thus treated, are said to last a considerably longer time than those prepared from ordinary fat; and if the wicks incorporated be prepared of hemp and cotton in equal proportions, and then dipped into an alcoholic solution of camphor, they are reported to be still more durable, and to burn without running or guttering.

Another receipt is to melt the suet with a quarter of its weight of water, being particular that any scum which may rise to the surface at the beginning is carefully removed, and when melted, it is strained off as usual, and the cracklings cleared away to the press. The fat is then returned to the boiler, with the quantity of water as before, having three-quarters of an ounce of nitrate of potassa, three-quarters of an ounce of chloride of ammonium—sal ammoniac—and one ounce of calcined alum, to every twelve pounds of tallow to be operated upon, disseminated through it; this mixture is then slightly boiled till bubbles cease to be evolved from the surface, after which it is drawn off into the moulds or blocks to be cooled; finally, these blocks are once more remelted after the greater portion of any foreign matter has been scraped off the sides and bottoms, and allowed to settle to deposit all impurities, afterwards it is run off, and is fit to be worked into candles.

The Dublin chandlers are reputed to be the best tallow candlemakers in the world—this was acknowledged to some extent by the jury of the Great Exhibition of 1851.

As in many other manufactures, the supposed secret upon which they work, to produce goods so highly commended, is nearly, if not wholly, confined to care and strict attention in the rendering of the fats, and in the subsequent operations of moulding, *et cetera*.

STEARIN AND STEARIC ACID CANDLES.—This branch of the business dates from a comparatively recent period, and indeed it is only by repeated improvements, made within the last dozen years, that it has attained to its present state of excellence. With the physical and chemical properties of stearin and stearic acid, the reader has already been made acquainted, as also with the method of preparing them in a state of purity. The processes described would not, however, answer in extensive factories, where many tons of the material are worked daily; the value of the candles made from it would not pay the cost of preparing its components.

In procuring stearin and stearic acid for candles, the object is not to obtain these bodies in a state of absolute purity, but to have them as free from the olein and glycerin, and portions of the margarin, to which they are united in the natural fats, as is possible by the means employed. The same principle pervades the manipulations on a large scale, as that already described—the object in view is the removal of the glycerin and olein, although, in the processes referred to, the operations were conducted with much greater care and minuteness than could be bestowed in an extensive business. It will be necessary, therefore, to describe here the method adopted in large establishments.

CHEVREUL'S investigation on the fats was the first step towards the employment of stearic acid and stearin in the preparation of candles; additional information was added to that derived from the researches of this chemist by the labors of BRACONNOT and others; and ultimately the tallow treated according to the processes pointed out by them, and divested of its olein and glycerin, was used for the making of candles by **CAMBACERES**. The manufacture, however, did not succeed on account of the imperfections of the methods adopted, which were such that better illuminating materials could be procured at a less cost than the new patent candles. On the Société d'Encouragement offering a premium of four thousand francs to the person who would discover a means of manufacturing a cheap, and at the same time superior candle, the spirit of inquiry was excited by the munificent reward, and as the result a great improvement took place, which much lowered the cost of candles, while in point of quality they were considerably improved, instead of being deteriorated. From time to time various alterations have since been introduced in the method of working, but still retaining the principle on which the original amendment was suggested.

GAY-LUSSAC's patent, sealed in 1825, specified that the fat, after being rendered, should be boiled with either potassa or soda, in order to form a soap, and to remove the glycerin with which the fatty acids are united. The saponaceous compound thus produced was next to be decomposed by an acid, in a capacious vessel, and in the presence of much water, the whole being heated by steam injected in any convenient way, and kept well agitated during the operation. After the decomposition was completed, the contents of the vessel were allowed to remain at rest for some time, till the fatty acids collected upon the surface of the water, which could be drawn off by a discharge-cock at the bottom of the tub, carrying with it the alkaline salts resulting from the decomposition of the soap. To free the fatty acids completely from any traces of the alkali or saline substances, a quantity of fresh water was thrown in upon the fat, the steam again allowed to enter, and the contents of the tub agitated as before; and after a short time the whole was left to cool, and finally the water drawn off from the solid layer of fatty bodies. This mass was then submitted to considerable pressure, in an apparatus similar to that used in extracting oil from seeds, by which the liquid acid—oleic—was discharged, leaving the solid residuary matter—stearic and margaric acids—in every respect similar to spermaceti; this was the substance which was employed for making the stearin, or rather stearo-margaric acid candles. Such was **GAY-LUSSAC**'s method, but the operations are now performed by a more economical process; instead of potassa and soda, lime is advantageously employed to discharge the glycerin, and form lime salts with the several acids. This greatly lessens the price of the stearin candles.

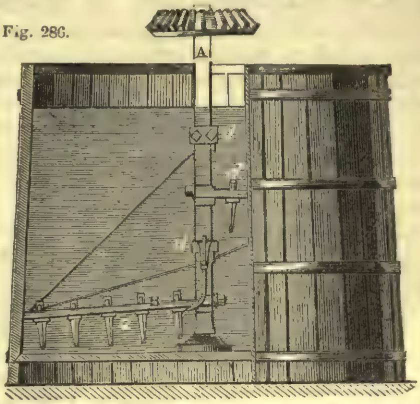
The utensils employed in conducting these operations in most factories, are large wooden tuns closely covered, and into which a steam-pipe enters from an adjacent boiler. The suet or rendered tallow is introduced into these tuns and melted; then pumped out into a second tun of a similar construction, but supplied with additional machinery for agitating the contents. In this tun, the hydrate of lime is mixed with the oily fat in the proportion of fifteen per cent. of its weight, the lime being made into a moderately thick cream with water—one and a quarter gallon to the pound of lime. Care should be taken to have the lime caustic, and as pure as possible: if it be not caustic, it will be ineffective in decomposing the fat; an increased amount of acid will be required afterwards to remove it, and of course this useless working will be so much to the manufacturer's loss. When there are much impurities in the lime these may become insoluble, and are with difficulty separated from the mixed acids afterwards. Having thoroughly blended the cream of lime with the tallow in the decomposing tun, the cover of which is fastened down tightly, the steam is turned on and allowed to play upon the contents for six hours, keeping the whole constantly agitated by the aid of the apparatus provided for this purpose; at the end of that time, it generally happens that the decomposition of the simple fats, and the combination of the acids with the lime, are completed; but it often occurs, particularly when the lime has become carbonated, or from some similar causes, that a much longer period is required to remove the whole of the glycerin, and form lime salts with the acids of the tallow. The only test which the operator can apply to judge of the saponification being perfected, is to take out a small portion of the thick compound, and allow it to deposit the insoluble lime soap; the supernatant water is then poured off, and the subsided matter cooled; if this mass appears smooth, homogeneous, and semitransparent throughout, makes a sharp noise on being fractured, and goes into powder on being ground in a mortar, there remains no undecomposed fat. The steaming in the vessel should be continued till the contents give these reactions. When the test alluded to indicates that the saponification is completed, the steam is shut off, and a quantity of cold water gradually added, keeping the machinery in motion during the time. This drenching with cold water first causes the insoluble soap to assume a granular appearance, and secondly, takes up the glycerin, and as soon as this state is attained by the entire matter, the agitation is discontinued. When, after a short interval, the whole has settled, the water added, together with the glycerin of the fat, is drawn off by means of a plug hole at the bottom of the tun, protected in the inside by a sheet of fine copper, wire gauze, or cloth, so that the small particles of the soap are not permitted to pass out when the plug is removed. As soon as the whole of the water has exuded, the outlet is stopped up, and another sperge of cold water poured upon the soap, the agitation to take place as before; and after a time this water is drawn off in the same manner as the preceding.

By such repeated washings the whole of the glycerin is removed, and nothing remains but the lime compounds with the stearic, margaric, and oleic acid of the fats, together with any slight excess of the reagent that may be taken to insure the success of the decomposition.

The next stage in the operations is the decomposition of the several soaps and the removal of the lime, which is performed through the agency of an acid, the affinity of which for this base is more powerful than that of either of the fatty acids which constitute the soap. **MORFIT** recommends, for this purpose, to take two hundred and fifty pounds of concentrated sulphuric acid, afterwards diluted with two thousand pounds of water for every one thousand pounds of fat saponified; this is to be poured into the tun upon the soap, the steam turned on in a gradual uniform stream, sufficient to heat the mixture to about 200°, taking care, however, that it does not boil; meanwhile the whole is kept in gentle agitation to insure decomposition—a point ascertained by the disappearance of its granular arrangement, as well as by the fatty bodies rising to the surface.

Much care is necessary on the part of the attendant during this period, in regulating the entrance of the steam, for if the temperature becomes elevated, with the presence of a strong acid and exposure to air, the color of the products will be injured; hence the best and most reliable way would be to check the entrance of the steam at intervals. The tun may be left uncovered during the decomposition without any disadvantage arising. When the separation of the lime is complete, the contents of the tun are left to rest for some time, in order that the sulphate of lime may be entirely taken up by the water, and removed from the fats which occupy the upper strata. When this happens, the plug hole at the bottom of the tun is opened, and the solution of sulphate of lime, with any other lime salts or caustic lime that may be left, and held mechanically in the liquid, is drawn off. A quantity of hot water from an adjacent boiler or wooden vessel is then let in upon the residual matter, and the agitator set in motion; the warm water melts the fats, and, by the aid of the agitation, the separation of any saline matter or excess of lime is facilitated. After the melting and agitation has been continued for some time, the contents are allowed to repose as before, and after the water and any impurities have settled to the bottom, they are drawn off through the outlet. This mode of washing is continued till the last traces of the mineral compounds are separated, and then the crude fatty acids reheated to the melting point, and drawn off into casks or trays, to *granulate* or crystallize. The trays employed are made of tin, and have a capacity varying from sixteen to twenty inches in length, ten to fifteen in breadth, and two to three inches deep: after being charged with the melted fatty bodies, they are ranged upon convenient shelves in an appropriate room, the temperature of which stands between 70° and 90° Fahr.; here they remain for two, three, or more days, till the stearic and margaric acids assume a crystalline form, or *granulate*. It has been already shown, that the oleic acid does not solidify at this temperature, and, therefore, at the termination of the granulation, this compound may be observed upon the solidified matter on the trays in the form of drops or exudations. The decomposing or saponifying tun, spoken of in the foregoing pages, is represented in the annexed woodcut—Fig. 286. It is constructed of oak or cedar wood, well bound with stout iron hoops, and covered tightly. In the centre of the tun, a shaft, A, to which a bevelled cog-wheel, gearing into another fixed on the main shaft from a steam-engine, but which is not shown in the drawing, is appended. In the interior of the tun, four brass arms, *d*, studded with large teeth, extend from the shaft, turning round with the motion of the axis, and keeping the contents in brisk agitation. These arms are often constructed of wood, as also the teeth, making the fastenings with brass. The heat is communicated by means of a convoluted steam-pipe placed upon its bottom, and perforated with small holes. This pipe is furnished with a stopcock, for the purpose of shutting off the steam, or otherwise regulating it.

Fig. 286.



When the mass in the tin tray has crystallized or granulated as far as possible, it is removed to a machine, where it is cut into thin shreds by a knife attached to a revolving wheel, against which the fatty matter is made to press. These sheets are interlaid with coarse matting, made of baya or fibre, or each of the cakes may be at once enveloped in it, and placed under a hydraulic press, and the chief part of the oleic acid expressed. The apparatus used on these occasions is generally that of **Maudslay** and **Field**, seen in the annexed figures.

Fig. 287 is a front, and Fig. 288 a side elevation.

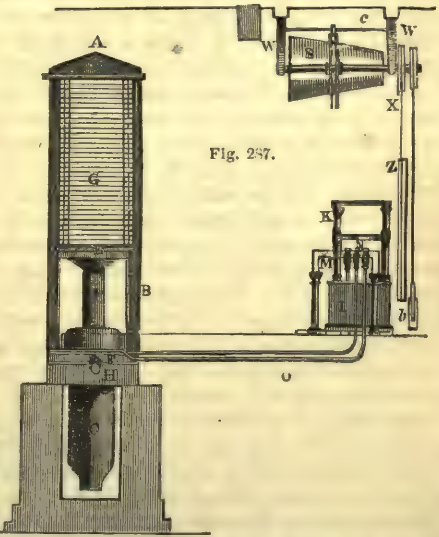


Fig. 287.

The same letters indicate the same parts in both. A A shows the presses as they appear in the front view, and B the frame in which they are enclosed; C is the cylinder, D the piston or ram, and E the follower. Recesses are formed at the bottom of the presses, F. The material alternated with the mattings, or canvas, or woollen bags, is shown at G. At H are the apertures through which the oil issues from the expressed material; and the space at I is the cistern wherein the pumps are fixed, while at N may be seen the branch pipes, enclosed in the case, M, and each having two stops or plugs, by the regulation of which the action of one of the pumps may be intercepted from, or communicated to, one or both presses. By these, one or both presses may be discharged when the operation is finished. O indicates the pipes connecting these branches with the pumps; and the drum, from which motion is given to the pumps, is seen at R, fixed upon the main shaft, *y*, and worked by the steam-engine. This cylinder is made to act upon a similar one, S, which works the pumps by an endless strap. A long screw, bearing a nut, works along the whole length of the drum, S; a fork, or guide, is shown for moving the strap, T; W W are two hanging bearings to carry the drum, S; X is a pulley on the spindle of this drum; Z, a fly-wheel with groove on the edge, driven by the pulley, X. The pumps are worked by a double crank fixed on the axis of the drum, S. At the commencement of operations, the larger of these pumps is set in motion to induce a gentle pressure, and when considerable quantities of the oleic acid have been forced out, the smaller one is worked to give additional force to the machine. *a* is a pulley on the end of the long screw, round which an endless cord passes twice, also under a pulley fixed in the weight, *b*; on raising or lowering this cord, the forked guide, and the leather strap, T, are moved backwards and forwards by means of the nuts fixed in the guide, so as to accelerate or retard the speed of the pumps at pleasure; *c* is a piece of iron, with a long slit, in which a pin, attached to the fork, travels, to keep it in a vertical position.—*Ure.*

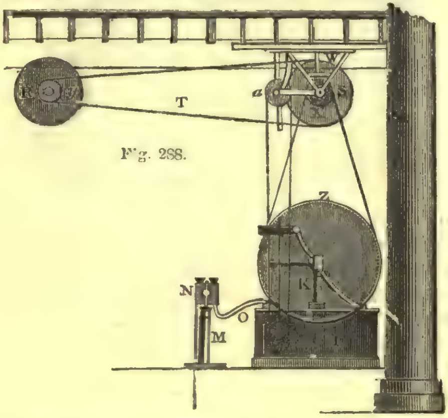


Fig. 288.

In placing the blocks or sheets of fat interposed or enveloped, as the case may be, in the coarse covering, a plate of wrought-iron is put in between the cloths at regular intervals, till the frame is filled; the sheet-iron plates prevent the whole mass from being blended too tightly together by the great pressure communicated.

After the pumps have been set working, and the pressure has been exerted till no more of the fluid material exudes, the machine is loosened, and the expressed layers taken away to remove the covering. The fat, by means of this compression, becomes so dense and hard as to be scarcely marked by the nail. The cakes, however, still retain a further quantity of oleic and margaric acids, to abstract which, they are usually submitted to a second and more powerful operation, particularly when the products are required for the best kinds of stearic acid candles. To accomplish the further purification, therefore, the pressed cakes of fat are introduced into a large covered tub constructed of wood, and bound firmly with strong iron hoops; into this vessel steam is forced during five or six hours; it is then shut off, and when sufficient time has elapsed for the water to fall to the bottom, the layer of fatty acids is conducted into moulds and carried to another part of the factory, the temperature of which must range, as was previously said, from 80° to 90° Fahr.

When the sebaceous substance has crystallized or granulated in these frames, which usually happens in twenty-four or forty-eight hours, it is removed, and brought to the graining machine—a contrivance like that already alluded to for cutting the masses into sheets, only that, in consequence of the fat being more crystalline at the second operation, the slices detached by the knife crumble into fragments, as if they had been rasped off. This meal is conducted by a sluice from the rasping machine to a convenient recipient, and out of this it is filled into canvas or woollen bags, and these again are by many enclosed in coarser ones, made of hair or cocoa-nut fibre, *et cetera*, and submitted to another expression. No more of the substance should be introduced into each of these bags than will form a cake of the lineal dimensions of the face of the press, while the thickness should not exceed half an inch. On the filling being performed, the bags are deposited in the press as before, with the metallic plates between each; but as the more fluid acid bodies are less abundant now than on former occasions, they are much more difficultly removed, and only by more powerful machinery.

These machines are worked by pumps set in motion by a shaft connected with a steam-engine, as on the previous occasion. The slight increase of temperature which is supplied, causes the expulsion of a portion of the margaric acid, together with the last traces of the oleic, leaving the solid stearic mixed with margaric acid in a tolerably pure state. When the power necessary to expel the fluid bodies has been given, the press is kept at a stand for about a quarter of an hour and then unlocked; the bags are now taken from the case and laid upon a table adjoining, the interposed plates of metal being sided in an appropriate place, where the necessary temperature will be communicated to them. The cakes of stearic acid are then denuded, and the fringes, which, on account of their being in some degree exterior to the action of the press, retain some of the more oily acids, are carefully cut off with a knife, reserving these fragments to be submitted to another operation. When the cakes of margaro-stearic acid have been further freed from any adhering matter by scraping, they are thrown into a clean wooden tub holding a quantity of water, and melted by injecting steam into it.

Two different processes are now followed, according as the manufacturer intends to bleach the candles after moulding, or the material before it is cast into candles. In the first instance, a small quantity of strong sulphuric acid—four or five pounds—diluted with twice its weight of water, is added; this mixture is intended to separate any inorganic base which may still remain in the fat, as well as any other matter that may be present, by carrying them to the bottom of the tub. When the acid liquor has subsided, it is drawn off by a spout, and the residual matter repeatedly washed with hot water till the washings cease to be sour. The compound thus purified is run into tin or copper pans of a cylindrical shape, where it is allowed to cool. These blocks of fatty matter, on being broken, exhibit a highly crystalline appearance, a feature which, if not counteracted, would prove deleterious in the candles; they are ready to be melted previous to moulding, any adhering matter being first carefully removed. To destroy the tendency to crystallize, the melted material is mixed with a proper proportion of wax, which gives additional beauty to the candles. It was customary, at no very distant period, to add about one part of arsenious acid to a thousand parts of the compound, thus purified, to prevent it assuming a crystalline form in the candle; but this practice, having been strongly condemned as injurious to the health of the community, has been discontinued.

If it be desired to have the stearic acid bleached before being moulded into candles, the melted compound, after being withdrawn from the press, and the fringes of unpressed material removed, is drawn off from the tube into a smaller vessel, perfectly clean, and furnished with an agitating apparatus nearly similar to that represented in Fig. 286, and also with a steam pipe for the purpose of heating the water. The fat is here melted by hot water, and about four pounds of nitric acid added to every hundred pounds of the fat, keeping the mixture briskly agitated for about an hour; the introduction of the steam is then discontinued, the acidulated water drawn off, and the partly bleached matter treated repeatedly with hot water, stirring well at each addition, and removing the water as soon as settled to the bottom. The last washing should be performed merely by boiling water without the aid of the agitator, and the fatty matter, while yet in a melted state, is run into tubs, or pans, of a convenient size, and allowed to solidify. The substance now presents a brilliant crystalline aspect, and if mixed with a small proportion of wax when made into candles, it appears equal to any spermaceti, whilst this prevents the tendency of the fat to crystallize in the moulds.

A process has been adopted of late years in France, for preparing stearin and stearic acid from tallow, which, to all appearance, is well worthy of attention; the same has been adopted by MORFIT, for preparing these materials from lard, with success. It consists of boiling the tallow with a proportionate quantity of sulphuric acid—ten to fifteen per cent. of the strong acid diluted with a certain amount of water—and after the fats have been acted upon, hot water is added, and the whole allowed to cool. This treatment affords at once stearic, margaric, and oleic acids, and dispenses with the tedious operation of saponifying with lime. That sulphuric acid acted in this manner upon the natural fats, giving rise to the compounds sulpho-stearic, sulpho-margaric, and sulpho-oleic acids, together with sulpho-glyceric acid, was known from the labors of FREMY in 1836. Water decomposes the stearic, margaric, and oleic compounds of sulphuric acid, by the removal of the latter, whilst it retains the sulpho-glyceric acid. Latterly, this method of procuring stearic and margaric acids has been very generally practised, and the issue promises fair prospects of advantage to the manufacturer. These, however, are not the only advantages, for, after the fatty body has been washed with water to remove the last traces of sulphuric acid, it is melted, and, when on the point of congealing, about fifteen per cent. of its weight of spirit of turpentine is intimately mixed with it, and then it is cooled in trays or moulds in the ordinary way, and pressed as already described.

Mr. TILGHMAN has lately patented a process by which the preparation of the fatty acids, whether from tallow, palm, or cocoa-nut oil, is simplified, and at the same time, to a certain extent, the substance is bleached and deodorized. The agents used are heat and pressure conjointly with steam.

The annexed figures represent the apparatus. Fig. 289 is a vertical section, and consists of a vessel, A, in which the fat is macerated with hot water to make it into an emulsion; this is accelerated by the disc-shaped piston, B, perforated with numerous holes, and moved rapidly by machinery. C is a force-pump connected to the vessel, A, and used to drive the liquid through the coil of piping, D D D D. The latter is made of iron; it is an inch in diameter externally, and only half an inch internally, and is heated by the fire, F. At the extremity of this pipe a worm, G, cooled by water, and having a valve, H, fixed to the lower end, is attached. The valve can be so loaded that the expansion of the materials in the tube when it is heated to its working point will not be sufficient to lift it, provided the pump is not in motion. Fig. 290 is a horizontal section of the preceding, showing the flue, E E, circulating the casing traversed by the pipe, D D D D. By means of a thermometer, constructed of a number of substances the fusing point of which varies, the heat of the tube is measured and retained at the temperature best suited for the operation. Four holes, half an inch in diameter, and three inches deep, are made in the iron jacket in which the pipe, D, is encased, and into one or other of these, tin, bismuth, lead, or nitrate of potassa is introduced. When the pipe becomes hot, the attendant dips a straight iron rod into these, and according as it sinks into the one or the other, he tells whether the heat is 440°, the melting point of the tin; 510°, the fusing point of bismuth; 612°, of the lead; or 660° Fahr., the degree at which saltpetre is liquefied.

During the working of this machine, care must be taken that the heated pipe is kept quite full of the mixed liquid by means of the pump. Under these conditions the fat is decomposed in ten minutes; and the temperature, according to the nature of the material, may range from the melting point of bismuth to that of lead, although a higher degree will not, in some instances, prove detrimental. The pressure employed during the operation is said to be under two thousand pounds on the square inch. A vertical position is given to the pipes, to prevent that tendency of the fat and water to separate, as it is necessary that both should be in intimate contact during the passage through the heating medium. The product discharged from the end of the worm, H, is a solution of glycerin in water and fatty acids, and which are separated by subsidence in the receiving tank; the latter is treated in the usual manner, as described for purifying such bodies.

Fig. 289.

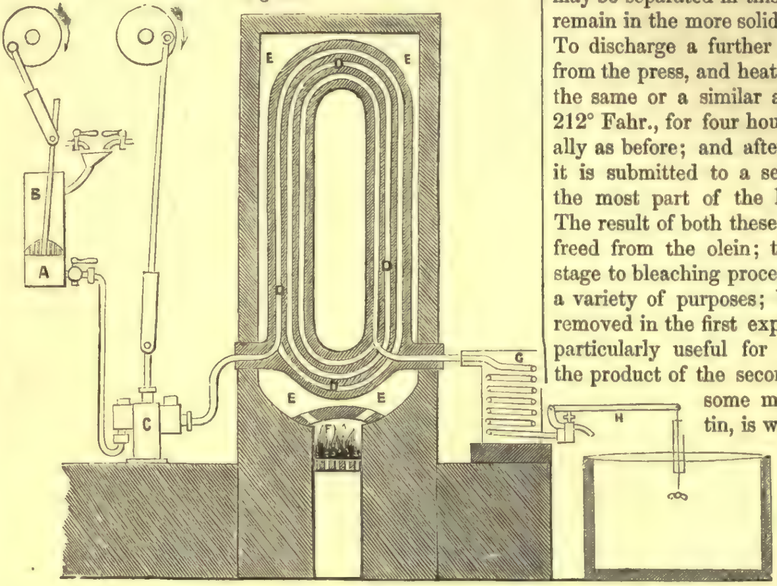
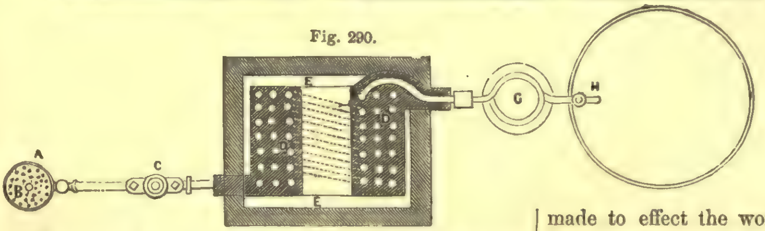


Fig. 290.



Such are the processes by which tallow and suet are prepared for making stearic acid candles; but besides these, many other products are employed, from which, by analogous methods, materials are obtained equal, if not superior, to the stearic acid of tallow and suet.

Palm and cocoa-nut oils are the most abundant of these other sources, and their use in the preparation of the best variety of candles affords an illustration of the comfort and benefit to be derived from the culture of scientific pursuits.

Palm oil, as imported, is a reddish-yellow semi-solid mass, though fluid in those climates where it is produced. It generally acquires a disagreeable rancid odor in the course of the voyage, arising from a decomposition of some of its more oleaginous constituents, the removal of which occasions considerable trouble. The more infusible principle in palm oil is palmatin, from which candles, generally called stearic, though sometimes named *palmatin lights*, are made.

In the course of operations usually followed, the first step is to liquefy the fat—which may be previously bleached—and to allow it to cool or granulate slowly. The melting is performed by steam in large iron-bound wooden tanks. After the first granulation, the solid matter is taken in portions of about thirty pounds, and encased in matting made from the fibre of the cocoa-nut, placed in a vertical hydraulic press, with metallic plates between each pair as before specified, and the most of the olein removed. As, however, the olein is the principal constituent, although a great deal of it may be separated in this way, yet considerable portions remain in the more solid cake enclosed in the mattings. To discharge a further quantity, the cakes are taken from the press, and heated by steam a second time, in the same or a similar apparatus to the preceding, at 212° Fahr., for four hours, and then left to cool gradually as before; and after the solidification of the mass it is submitted to a second cold pressing, by which the most part of the liquid constituent is expelled. The result of both these expressions is the solid matter freed from the olein; the former is submitted at this stage to bleaching processes, and the latter is turned to a variety of purposes; but as that portion of the oil removed in the first expression is very pure olein, it is particularly useful for lubricating machinery, whilst the product of the second expression, carrying with it some margarin, and stearin or palmatin, is well suited for making soap, and for this purpose it is exported in considerable quantities to the continental makers.

Many methods, some of which have been already mentioned under the several preceding heads, are resorted to for bleaching the cakes of solid acid. This may be done either by nitric acid, bichromate of potassa, or hypermanganate of potassa, but the course usually adopted is that by which air and moisture are made to effect the work. The substance is steamed in a vessel at a temperature of 212°, and as soon as liquid it is drawn off into a large trough through which a stream of cold water flows, so proportioned that the current contains about twice as much water as the liquid fat running into it. Solidification of the melted fat is almost immediately caused, by the excess of the cold medium meeting it in the trough in such a way that it forms small flakes and globules. The stream carrying those particles along, falls into a reservoir where the fatty matter floats on the surface, and is thence taken and exposed to the blanching action of air and light; in a short time the yellow color is succeeded by a beautiful white.

If it be necessary to submit the bleached matter to the hot press, it is granulated and enclosed in small portions in the envelopes used for this purpose; then put into the horizontal press, heated by a steam case to about 85° Fahr., and treated in the same manner as stearic acid from tallow already described, taking the precaution of paring off those portions of the fringes which may be discolored by any oleic acid, and collecting them to be submitted to a second operation; and afterwards the expressed bleached cake is subjected to a final process of refining, as follows:—The cakes are melted by steam, and two per cent. of sulphuric acid added, some water being already introduced; the sulphuric acid unites with any extraneous matter and also with the glycerin, and carries them with it into the water at the bottom. To effect this more completely, the fat should be kept agitated till the acid gets sufficiently mixed with it, the whole is left to rest, and when the fat and acid liquor separate, the latter is drawn off; a fresh dose of hot water is added, and steam is again applied for the purpose of washing away the acid. At the termination of these ablutions the layer of fat acid is drawn off and melted in a clean vessel, and cast into blocks, which, when solidified, appear very clear and pure. This material is fused again before being moulded in the same way as that usually followed in this department, using in the candles the improved wicks previously described.

Coco-stearin is prepared in a similar manner to the preceding, from the butter of cocoa or cocoa-nut oil; but, on account of its very low melting point it is mixed with other more infusible fats, such as stearin from tallow, or stearic acid, to manufacture a species of candle called *composites*. The palmatin or stearin prepared according to the foregoing method, is sometimes used alone in candles; but it is more frequently mixed in the same way as cocinin or coco-stearin with other ingredients, whereby a candle of medium infusibility is produced.

Though such preparations answer the purpose of tallow candles very well, yet of late years, by a course of operations, grounded on chemical principles, to which the crude materials are subjected, products are obtained which can vie in point of beauty and utility with wax. This is effected by preparing the fatty acid from the palm oil, but as the leading features and properties of this body have been already laid before the reader, it will be needless to recur to them, and therefore the method of preparing the fatty acid, as practised in large factories under patent rights, will now be described.

HEMPBELL and BLUNDELL'S specification directs that the oil should be granulated and pressed as already pointed out, excepting that previous to saponification only one pressing is given. The cakes of fat are next melted in an iron pan with water, and twelve pounds of caustic lime, slaked, added to a hundred and four of the fat, and the mixture boiled for three or four hours, at a temperature of about 240° Fahr., during which period it is kept briskly agitated. When the combination of the fatty acids with the lime has been perfected, the fire is withdrawn or slackened, and a quantity of cold water gradually added, the lime soap being briskly stirred at the same time. This addition of the cold water, assisted by the agitation, throws the whole mass into a granular state. After the water is drawn off, the next step is the separation of the lime, and this point is gained by a novel procedure. As much chloride of calcium is taken as will yield, upon being decomposed with sulphuric acid, enough of hydrochloric acid to saturate the lime combined with the fatty acids in the lime soap. This is dissolved in water, and strong sulphuric acid added, to throw down the base, in the form of sulphate of lime. As soon as the precipitate has subsided, the supernatant acid liquor is drawn off, and added to the lime soap in slight excess; the mixture is then well stirred and left at rest for three or four days, to cause the combination of the hydrochloric acid and lime. At this period heat is applied, with the view of removing the lime salt and fatty acids, by dissolving the latter, and causing them to form a layer on the top. The solution of chloride of calcium is drawn off, and preserved to be decomposed for another operation by an equivalent of strong sulphuric acid. The fat acids are washed successively with hot water, and lastly, granulated and submitted to the hydraulic press, at a temperature of 75° Fahr., which discharges the oleic and portions of the margaric acid.

The bleaching and refining process is performed as follows:—The cakes of fat are taken and kept at a melting point in large shallow open pans, the bottoms of which are covered with water, for a period varying from one to twelve hours; in this operation the coloring principles are destroyed by the action of the air, assisted by repeatedly agitating the materials.

In refining this bleached product, the patentees employ two and a half pounds of peroxide of manganese and forty pounds of strong sulphuric acid, diluted with two hundred pounds of water to every thousand pounds of fatty acid. The fat being melted in a suitable vessel heated by steam, and furnished with an agitating apparatus, the above mixture is let into it by degrees, from another vat or vessel placed over the latter, and the agitating apparatus set in motion for two hours. After this period the contents of the vessel are left to repose for two days, then steamed a second time for a few hours at the boiling point, the whole allowed to settle, the acid liquor at the bottom next separated, and the fatty acid removed to conical stoneware vessels, lined with coarse filtering paper, and enclosed in a box heated by steam.

On melting the fat in these vessels, it passes readily through the paper, and any admixture of foreign matters is thus withheld. After filtration, the fatty acids are run into blocks; and, upon cooling, they will be found of a beautiful white color.

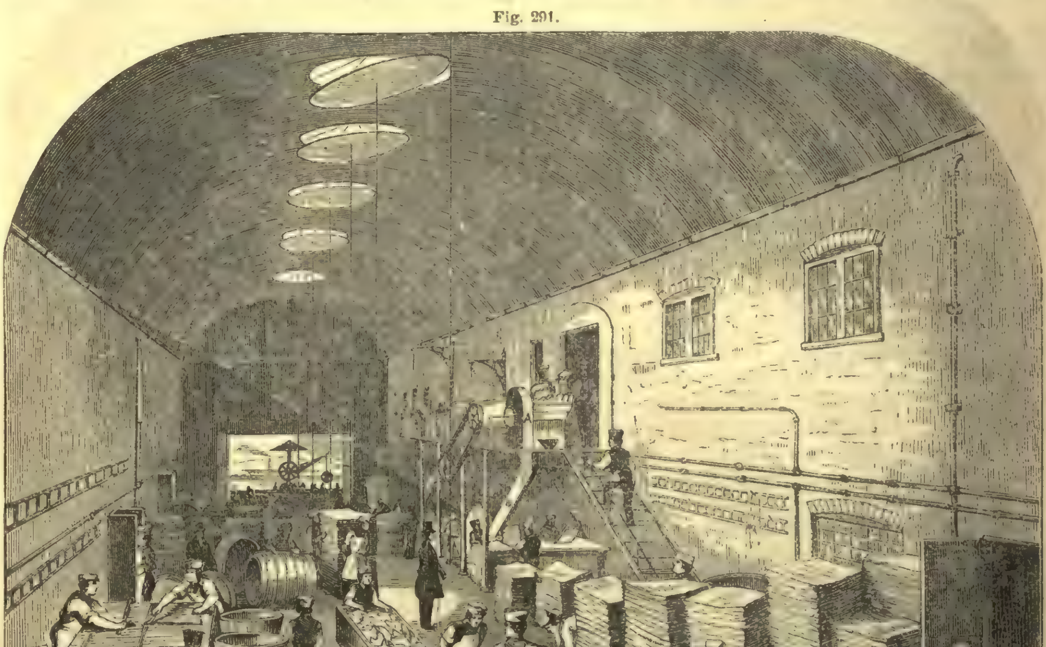
The effect of the manganese and sulphuric acid, in this method, is apparently to evolve oxygen, whereby any colored matter that might remain after the first action of the air is whitened; beyond this, it would appear that they afford no other advantage excepting that some substances may be carried down mechanically.

Other improvements have been lately announced for treating fats derived from vegetals, by which the fatty acids are prepared with less labor and expense than usual. The principal of these is that of distillation, and employing the products at once, or after further operations, to make candles.

FONTAINEMOREAU directs that the vegetal tallow should be heated in a convenient vessel, by injecting steam into it, at a temperature of from 316° to 352° Fahr. Before admitting the steam, the substance should be heated to 212°, and mixed with about one-third of its weight of water. A quantity of lime, in the proportion of three ounces to two hundred and twenty pounds, is slaked and added to the fat in the vessel, and the whole well agitated; after fifteen to twenty minutes brisk boiling at the above temperature, the lime is neutralized by the addition of an excess of nitric acid, in such proportion that there remains sixteen ounces of the acid to the forementioned weight of fat after this base is taken up. The mixture is then boiled for three quarters of an hour, and the evaporated water replaced by fresh quantities every twenty minutes. In two hours the operation is said to be completed. The nitric acid here is added with the view of bleaching the matters as well as of combining with the lime and any other impurities. When the bleaching has been sufficiently accomplished, the steam is shut off, and about a gallon and a half of water thrown into every hundredweight of fat, and then allowed to settle. This fat is then prepared for making candles, by subjecting it to a process of distillation wherein the heat is communicated by steam generated in an ordinary boiler, but heated afterwards to a higher degree by transmitting it through red-hot pipes before it enters the still. This process of distillation may be conducted intermittently by means of a double still, which is so fitted that it can be supplied at will with fresh quantities, the refuse matters being drawn off by the discharging cock. The distilled matters are either submitted to hot pressing, or made into candles at once, in which case the patentee adds a certain portion of stearin of tallow to destroy the crystallizable tendency. After these fats are pressed in the usual way, he proceeds to effect their bleaching by mixing them with a small per-centage of their weight of caustic potassa or soda, and after removing any deposit that falls down, he employs half a per cent. of chlorate of potassa dissolved in forty parts of water, acidulated with one part of sulphuric acid, and mixes this solution with the fat, then boils the whole for half an hour. On subsequently washing it to remove the acid and salts, the resulting compound is said to be very beautiful.

In the establishment of PRICE'S PATENT CANDLE COMPANY, which is acknowledged to be the largest in the world, the palm oil is subjected to saponification and distillation in a very efficient way. About twenty tons of palm oil are fused by steam in a large wooden vat lined with lead, and after it has settled it is pumped into an acidifying vessel, where it is heated by steam to about 350° Fahr. The steam is generated in the usual low pressure boiler, but the pipes through which it passes to the acidifying vessel are heated in a furnace, and thus it acquires a higher temperature. Concentrated sulphuric acid, in the proportion of six pounds to the hundredweight of the oil taken, is now gradually added. This is done by means of a leaden pipe extending across the boiler or tank, perforated with holes at the sides at a distance of six inches. The acid thus introduced equally over the mass, causes violent ebullition throughout, by which the two compounds get intimately mixed, even before any signs of decomposition are manifested. After a further heating of the mass for an hour or more, it is allowed to rest for six hours. It is now of a blackish color, and is pumped out to a vessel containing water slightly acidu-

Fig. 291.

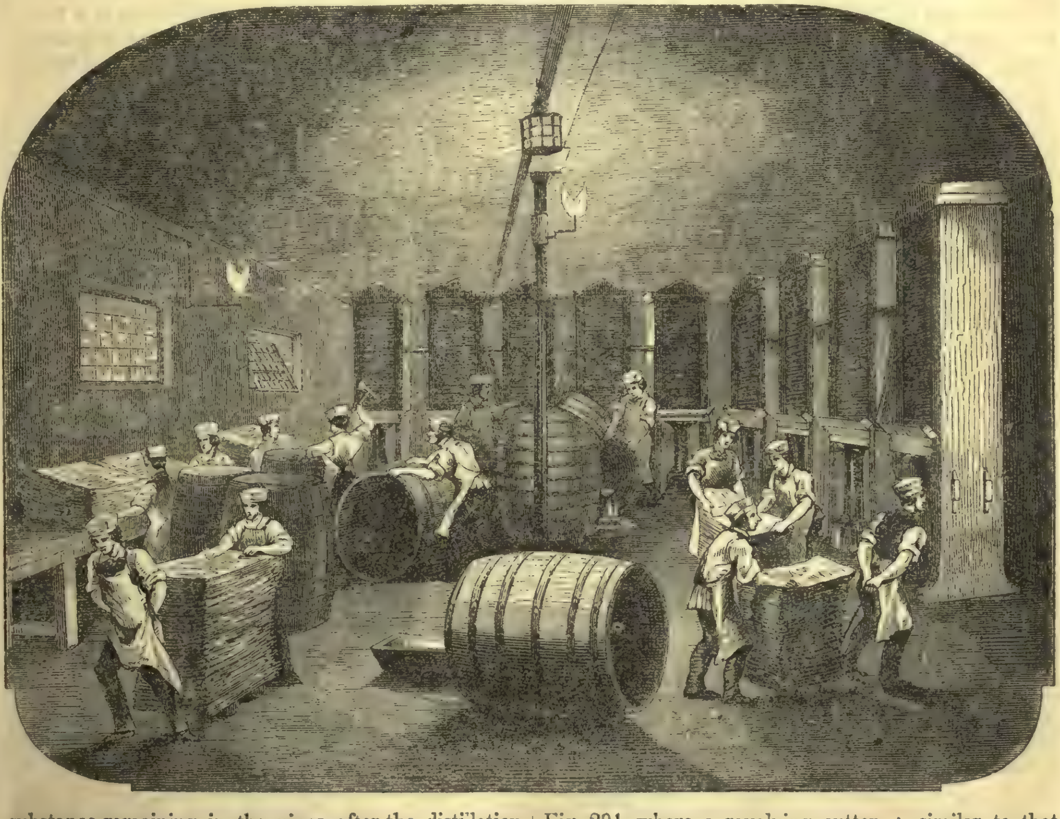


lated with sulphuric acid, and heated by steam blowing through it for two hours; after this period it is left at rest for twenty-four hours longer, and then the water removed. Both these vessels are well covered, and the vapors given off from them during the boiling are conducted by an exit pipe into the chimney.

After washing the fat, it is melted and raised by pumps to a tank commanding the stills; the latter are made of copper, and heated partly by an open grate fire, and partly by steam. A charge of the decomposed and washed fat, consisting of about five tons, is introduced into these vessels, and heat applied till it reaches about 560° Fahr., when low-pressure steam, raised to a higher degree of heat, is conducted into the mass, the air being excluded all the time. In order that the whole of the enclosed materials may receive an equalized temperature, the steam issues from numerous holes in a pipe convoluted on the bottom of the still, not unlike that of a sugar-house vacuum pan; and in this way the volatile parts are more readily carried off to the condenser, together with the steam. The mixed vapors of fat and water are conducted to a series of vertical pipes, the temperature of which exceeds 212°, and in passing through them the fatty matter is almost wholly condensed, while the steam flows off to a refrigerator, where it meets with a current of cold water, and is condensed, together with any minute portions of fat that might have escaped. These are collected in a tank, whence the water is drawn off at the bottom, while the fat floating on the surface remains.

After a considerable portion of the charge has been driven over, the residuary matter in the still is drawn off, and introduced into iron pipes raised to a higher degree than the still, by being placed in a furnace; a jet of steam, heated as in the preceding, is passed over it, by which the fatty parts are carried along, and atmospheric air excluded. By these means an additional quantity of fatty matters is obtained, while the substance remaining in the pipes, after the distillation is exhausted, is applied to the same uses as ordinary pitch. The product of these distillations solidifies into a tolerably-compact mass, and is used to a large extent for making the *composite* candles without being pressed; but these, although they are made with prepared wicks, so as to require no snuffing, are nevertheless much inferior in melting point and durability to those made from the purified material. To prepare the distilled acid fat for the pressing, it is conducted to the stripping department, shown in the centre of Fig. 291, where a revolving cutter, A, similar to that already described at page 414, cuts it into shreds of convenient size. It is worked by an endless strap attached to a shaft from the steam-engine, and the pieces that are lopped off at each revolution are conducted by the sliding tube, B, to the carriage, on which it is alternated with matting. As the material falls upon this carriage, it is spread by the workmen upon cocoa-fibre mats in layers of equal thickness, regulated by an iron frame. Every layer of material is covered with another mat, and when the pile has become sufficiently

Fig. 292.

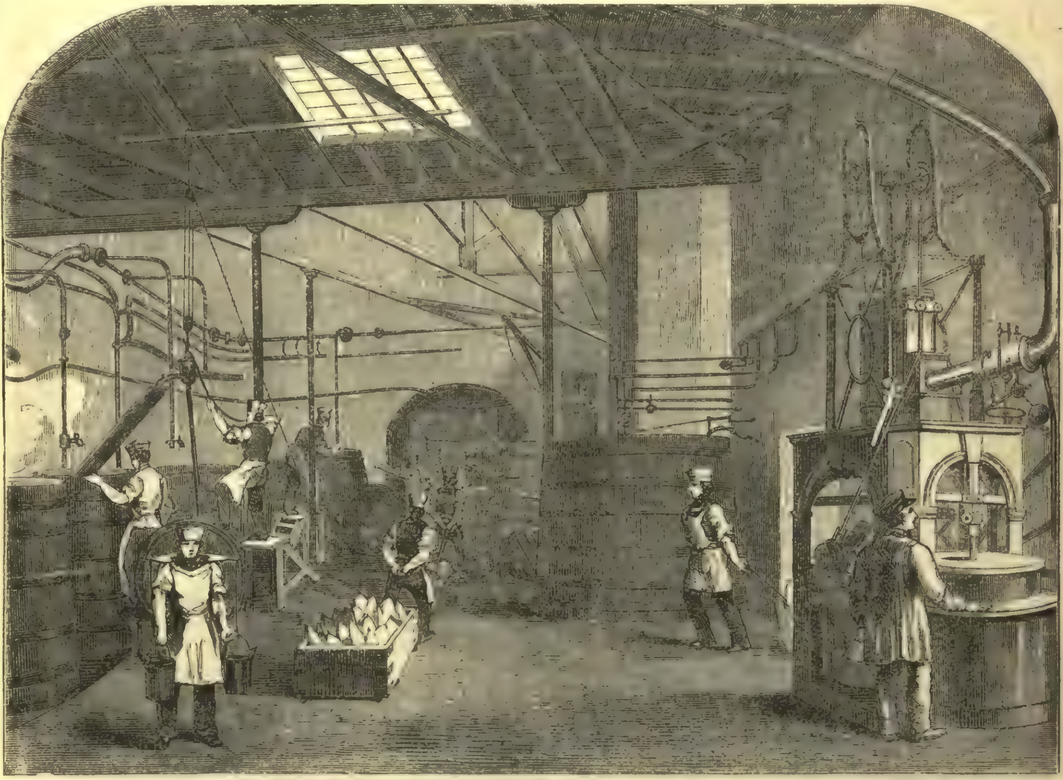


large, it is carried off to the pressing room, part of which is seen in Fig. 292, where about fifty hydraulic presses are at work. After the most part of the oleic acid has been extracted, the cakes, after fusion and granulation, as before explained, are further expressed in horizontal hot-presses, kept at a temperature of 85° or 90° by means of steam.

After the pressing has been performed, the mattings are removed from the layers of fatty matter; these are divested of the yet oleaginous edges by paring, and then brought to the steaming or boiling house, where they undergo another fusion with water acidulated with sulphuric acid.

This department of the manufactory is shown in Fig. 293, and is occupied by a series of large wooden iron-bound tuns, heated by steam pipes branching into them from a main connected with the steam boiler. Having been kept seething for some time, it is allowed to repose, and the acid water, after subsidence, drawn off; the residual fat is then washed with fresh quantities of hot water to remove all extraneous matter, and when this is accomplished, the fat is run into moulds or blocks. The material is at this stage sufficiently pure and hard to be manufactured into candles, which is effected by **MORGAN'S** apparatus. By this machine eighteen candles are moulded at once; the wicks, which are sixty yards long, and dressed so as to require no snuffing, are wound on eighteen separate reels, one for each mould. The ends of these wicks are passed through eyes at the point of each mould, and are held at the top of the frame by a set of forceps. Having wicked the moulds, they are passed on parallel railways through a closet heated by steam pipes previous to being filled, so as to bring them to a temperature of 120°. Each of the frames in succession are raised by a lever to the filling machine, and after they are charged they are passed along another line of railway, and during their course the contents of the moulds solidify. At this period the attendant removes the forceps which hitherto held the ends of the wicks, and also any excess of material remaining in the small reservoir at the top of the frame. Next, these frames are transferred to a carriage, and conducted to another line of railway which leads to the drawing machine, represented at page 428. As one set of candles is pushed out by the series of plungers, they draw with them into the moulds the wicks for the next lot; these wicks being held temporarily with one clip, whilst the candles are cut off close to the candle matter by a circular cutter. The forceps are now applied to the ends of the cotton, and as the plungers are returned they draw the wick tight. The frames, which during the operation are laid horizontally, are now restored to their upright position, and passed on upon the parallel supporters, or railway, through the heated chamber to be refilled. In this way the moulding is carried on intermittingly, and so quickly, that they can be made as fast as they are drawn, which is readily effected by a person accustomed to the business.

Fig. 293.



WAX CANDLES.—These articles, once so much used, have now a very limited consumption, and are nearly superseded by spermaceti and the beautiful stearic acid already described. In the commencement of this article on candles, a full account of the nature and properties of wax may be found, as also the method followed in bleaching it by exposure to air and light, and, therefore, a recurrence to that part of the business will be unnecessary.

Wax is not so well adapted for moulding as stearic acid and stearin, on account of the tenacity with which it adheres to the mould, and its great contraction on cooling; these difficulties are, however, in a great measure overcome by using glass moulds, only that they are so very fragile. By care, and a casing of gutta-percha, they last a considerable time. When the candles are to be drawn, the moulds are rapidly dipped into hot water, and taken out immediately, by which procedure the glass dilates sufficiently to allow the candles to be removed with facility. The practised hand draws the candles as the moulds are emerging from the hot water.

Although some candles of this description are made with moulds, yet generally the dipping and basting method is followed, and after sufficient wax has adhered to the wick, the finishing is executed by rolling in the manner about to be described.

The wicks for wax should be much less than those for any candles described, as it sheds a more brilliant and lively light than tallow or stearic acid. Twisted unbleached Turkey cotton is invariably used in this manufacture, as apparently the fibre resists the temperature of the highly heated wax during combustion better than the usual variety. Plaited wicks are not so well adapted as plain, since the plaiting somewhat diminishes the capillary attraction, and, therefore, the light is not sufficiently brilliant; and if a larger wick be employed to consume more of the material, it obscures the light, and also is apt to curl spirally in the flame, thus rendering it fuliginous. Various means have been resorted to for obviating these inconveniences. **SMITH** claims, as his patent right, the use of plaited wicks dipped in a solution of two ounces of borax, one ounce of chloride of potassium, one ounce of nitrate of potassa, and one ounce of chloride of ammonium, dissolved in three quarts of water, and afterwards drying them thoroughly. As the candles differ, it is unnecessary to enter particularly into what size of wick would best answer; suffice it to say that it should be so proportioned, as that when the candle is burning the whole of the melted matter will be absorbed, leaving the cup below almost empty, a full light at the same time being produced.

The usual method for making wax candles by immersion varies but slightly from what has been said of tallow dips, excepting that in the former case the ends of the wicks are protected from the wax by a small tin tube or tag, placed thereon for the purpose. Before using the wicks they are heated in a stove, so as to be well dried; they are then taken, and each wick threaded into the metal tag here alluded to, by means of a brass wire catch; an operation, however simple in itself, which should be performed with care, so that the end of the wick may not get charged with the melted material.

This being accomplished, the wicks are conveyed to another workman, whose business it is to pour the melted wax upon them. He performs this operation by suspending the wicks to a hoop placed over a caldron of melted wax, and pouring this matter on each in succession with a ladle, taking the precaution to cause the wick to revolve on its axis by the motion of the fingers; when the candles are about one-third made, they are allowed to cool for a short time, and then a second basting applied till they are half made, a point easily discerned by the eye of a practical workman, or otherwise by the aid of a balance. While still warm, they are subjected to a process of rolling between marble slabs to render them of a uniform thickness. The end of the candle is shaped at this stage of the process as follows:—The workman places five or six candles beneath his roller, the slabs being slightly moistened to prevent the wax adhering to them, and by means of a knife cuts off about three quarters of an inch, so as to remove the metal tag on the end of the wick. After this operation is performed, the finished ends of the candles are attached to the ring and suspended as before over the caldron, and the material ladled upon them till they are sufficiently large, when they are rolled as before; and finally, the conical end cut off by a knife to make them of equal length. To insure the rapidity of the manufacture, a workman is appointed to every department, so that the wax will not have time to harden before the candle is finished. Great dexterity is required on the part of the operative who rolls the candles to bring them to their uniform shape; but practice and diligent attention overcome all the obstacles to be met with in this particular.

When the candle is long, it is usual to bore a hole at the base in its centre to fit upon the spike of the stand upon which it may be placed, and lest this might cause the wax to crack, the end is bound round with a riband stiffened or imbued with melted wax. The ponderous lights burned in Romish churches are made by spreading the wax upon a slab, and placing the wicks horizontally upon it, then folding over the sheet of wax, and finishing the candles by rolling in the usual way.

Wax tapers are made by winding the wick upon a drum, and leading it under a guide roller placed in a trough of melted wax; from this it passes through a series of holes on to a second drum, the operation resembling somewhat that of wire-drawing. A little turpentine is added to render the wax pliable. Wax candles are generally colored—

Blue—With artificial ultramarine.
Green—With a mixture of verdigris and emerald green, or verdigris only.
Yellow—With chromate of potassa—chrome yellow.
Red—With vermilion, and
Pink—With madder lake.

SPERMACETI CANDLES.—The candles made from spermaceti are highly prized on account of their beauty and illuminating qualities, though their cost is not so high as that of wax candles, for which they have lately been substituted to a great extent. In the introduction to the fabrication the general properties of this body have been discussed, so that it only remains to give a brief description of its purification and manufacture.

The first step is to separate the solid or *head matter*, as it is called, from the sperm oil as it comes from the ships, which is done by filtering it through a long cylinder of bagging lined with linen. The bags are so constructed that, at one end, they are attached to a feed pipe opening into the reservoir, elevated four or six feet above it, while the other end is bound by a cord. On opening the feed pipe, the cylinder is readily filled, and the pressure then communicated by the stock of matter in the tank forces the oil through in considerable quantities, while the solid spermaceti is retained. Autumn and winter are the seasons for the filtration of the sperm oil, called bagging.

From the bags being open at both ends, the crude or *bagged sperm* is easily removed; it has a dingy brown color, in consequence of the oleaginous matter which it retains. Considerable portions of this oil are abstracted by the first pressing, which, in large factories, is applied by the hydraulic, though in lesser works the screw press is used with effect; in either case the sperm is enclosed in suitable quantities in hempen bags, and placed in the frame with plates interposed between them in the usual way. After receiving the pressure of about eighty to ninety tons, and when no more oil is afforded, it is taken out and melted as directed for stearic acid, then drawn off into tinned cases and granulated; finally, these blocks, after being thoroughly crystallized, are taken and grated to coarse powder by means of a revolving cylinder studded with knives; this powder, which is collected in a suitable bin beneath the cutter, is filled into cloths with twine wrappers, and subjected to the action of a much larger hydraulic press, capable of exerting a force of six hundred tons. Some solid matter is forced out with the oil at this stage, and on this account the latter must be passed a second time through the filtering bags.

This completes the process of cold pressing; still, a large quantity of oil is retained, and cannot be separated by mere pressure. Recourse is therefore had to saponification. For this end, the blocks of spermaceti are melted in a large iron vessel, and then boiled for some time with a solution of caustic soda, specific gravity 1·109, in the proportion of a gallon and a half of the lie to forty of the liquid fat. In this way the oil combines with the alkali, and rises to the surface in the form of soap. Should there be an excess of alkali over what is necessary to combine with the oil at the boiling of the liquid, it would act upon the solid matter and convert it into a soap which would be carried off with the remainder of the impurities. To prevent this, the solution of the alkali should be weaker, or the melted matter ought to be maintained at a low and equalized heat till the oil is taken up, the combination being assisted by stirring the mass. The melted material is now allowed to repose at this gentle heat, during which the soap that has been formed rises to the surface and is carefully skimmed off. To remove all the saponaceous compound in this operation, the whole of the material is raised to about 250°, and washed with small successive portions of water; meantime the scum, as it rises to the surface, is carefully removed, and the whole of the melted matter is clear. It is now drawn off into flat tin moulds, and left to crystallize; after this is done, the cakes are again ground to powder and submitted to hot pressing in bags of linen, interleaved with horse hair mats and heated iron plates, in the same way as stearic acid in a horizontal steam press.

Finally, the cakes are once more melted and boiled with a strong alkaline lie, at a temperature approaching 235° Fahr., taking care to remove any extraneous matter that may rise to the surface during the operation. When no more impurities are thrown up, the spermaceti is washed, by adding water at intervals in small quantities, the heat being moderated a little at the same time, and as the water falls to the bottom it effects a further purification, leaving the supernatant fluid colorless. It is now cast into blocks and crystallized, and stored as candle stock. Spermaceti is usually mixed with three per cent. of wax to destroy its highly crystalline structure; it is moulded in the usual way, and plaited wicks prepared that require no snuffing. Occasionally, the spermaceti candles are cast without any admixture of wax, the moulds being raised to a higher temperature just as with stearic acid. English manufacturers, in order to make the spermaceti appear like wax, use gamboge to give the desired yellow tint; such candles are known as transparent wax.

Before closing this account, it will be desirable to turn attention for a short time to a subject of paramount importance as regards scientific interest and novelty, and which may be looked upon as the culminating point in the art of illumination by candles. The fact here alluded to is the obtaining of coal olefiant gas in a solid form, capable of being used like ordinary candles. Paraffin has this constitution, and fulfils the requisites of coal gas in the ratio of its consumption, but hitherto it was a point of some difficulty to procure it, and, therefore, as a material for candle-making it remained unnoticed.

In the preceding pages, as well as when speaking of wax, the mode of preparing it and also its composition and properties are mentioned. The quantity of it produced in the destructive distillation of organic matters is very small; besides, the trouble which is incurred in purifying it from the many consecutive bodies in the distillates would not be remunerative. Wax, which affords a moderate quantity of this, or an analogous body, is too expensive a source, and the attempt which has been made to obtain it from peat does not appear to be very successful. M. SELLIGUE, in the distillation of the schists, found in the liquids which passed over about forty per cent. of fixed oils, which afforded about three per cent. of paraffin. Many bituminous bodies, such as ozackerite, hatchetin, *et cetera*, yield it in notable quantities; still, it appears that no effort has been made to produce it in sufficient abundance to be employed in manufacturing candles.

It has been hinted that Mr. YOUNG has overcome this difficulty, which hitherto stood in the way to a certain extent, by distilling coals at a low, instead of the application of a very elevated degree of heat, as is customary in the manufacture of gas. By so doing it is said that, on distilling Bathgate cannel coal, he obtains forty per cent. of oil, which is used for illumination and various other purposes, and ten per cent. of paraffin.

Paraffin is much better adapted for illumination than any of the fatty acids or other bodies as yet alluded to, since it is entirely composed of carbon and hydrogen, united in equivalent proportions. It is this body that gives to ordinary coal and oil gas their illuminating power; and any means which would produce paraffin in abundance to answer the requirements of the community, at a moderate cost, would be an invaluable addition to domestic comforts.

Very beautiful specimens of paraffin candles were exhibited in the Crystal Palace.

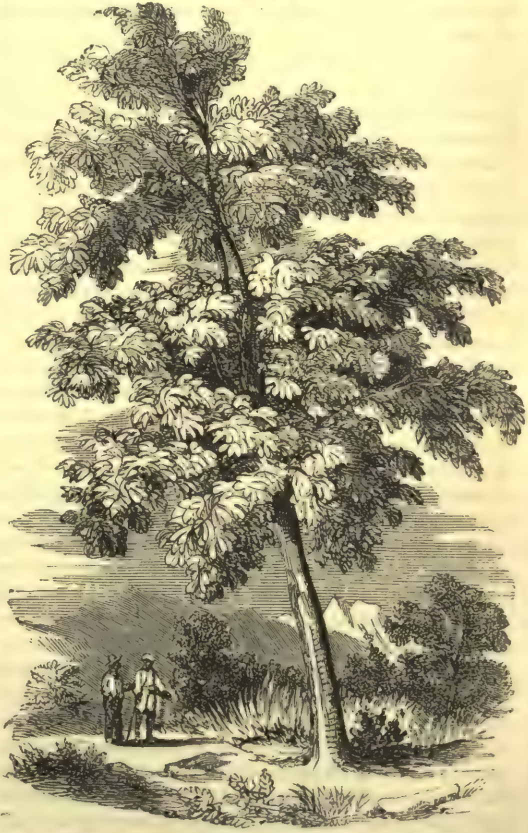
Statistics.—The manufacture of candles has considerably augmented of late years; and although it is difficult to ascertain its real extent, still the annual produce may be taken at sixty thousand tons. The increase may be inferred from the annexed table of the exports:—

Year ending January 5th	Quantity in pounds.	Declared value.
1854	3,382,632	£129,595
1855	3,880,248	175,852
1856	5,200,368	251,059

CAOUTCHOUC.—Gum Elastic or India-rubber.—*Caoutchouc*, French; *Federharz*, German.—This substance was introduced in the beginning of the last century in the shape of bottles; and its chief use for a considerable period was confined to erasing the streak of black-lead pencils on paper. It was brought from America; but very little was known of its history till the publication of M. De la Condamine's account of it in the transactions of the French Academy in 1736. In this report, it was stated to be the inspissated milky juice of a tree called, by the natives, *Hevee*. Frismau discovered the same tree in Cayenne in 1751; and since then it has been shown that various other trees—Asiatic and American—yield it in great abundance. America and East India are the great sources whence commerce is supplied; in the former, the caoutchouc is said to be chiefly derived from the *Jatropha elastica*, and in the latter country, from the *Ficus* and *Urceola elastica;* but, besides these, it may be obtained from the *cahuca*, called also *hevea guianensis, Castilleja elastica, cecropia pelleta, ficus religiosa, undica, et cetera;* it is also found in the poppy, the lettuce, and some of the Euphorbiums, and other plants having a viscid milky sap seem to contain it. According to the account of Mr. Griffiths, noted by Parnell, the *ficus elastica* is the vegetal monarch of those forests wherein it abounds, and may be recognised at a distance of several miles from the picturesque appearance of its lofty and dense crown. Annexed—Fig. 294—is a drawing of the caoutchouc tree in the Kew gardens. It grows either solitary or in groups of two or three. On measuring the trunk of one of these, it was found to be no less than seventy-four feet in girth; and the height of the central tree of a group of three measured one hundred feet. It is computed that over forty-three thousand of these trees thrive within a length of thirty miles and a breadth of eight, in the forest near Ferozepoor, in the district of Chardwar, in Assam.

Caoutchouc is extracted from the tree already mentioned, by making incisions in the bark around the trunk, beginning at the base, or at the reflex roots, which generally lie exposed. A milky emulsion containing the caoutchouc exudes at these orifices, and is collected upon earthen moulds, which, as soon as they are covered with a stratum of the liquid, are taken and exposed either to the heat and smoke of a fire, or to the sun; and when the solid matter forms upon them, they are again applied to the liquid for a second coating; re-dried, and the process in this way continued till the coating of caoutchouc becomes half to one inch or more in thickness. The moulds are then broken, and the pieces of clay abstracted through the neck, leaving the solid coating in the shape of a flask. This is the crude bottle india-rubber of commerce, as obtained from South America; but it comes from the East Indies in the form of junks and balls. The Indian product has a lighter color than that from America, on account of its being allowed to inspissate in the heat of the sun, whereas that from the latter country is dried over a slow fire, and becomes blackened by the smoke. It is stated that the old trees furnish a juice which is richer in caoutchouc than any other; also, that that which exudes in cold weather is better than what runs in the sultry season; further, Mr. Griffiths states that the produce of the reflex roots which lie exposed, is more abundant in the elastic gum than any which is subsequently drawn off. Incisions are repeated once a fortnight, continuing them up the trunk and along the larger branches to the top of the tree.

Fig. 294.



Besides the ordinary solid material, the liquid juice has of late years been imported in glass or other impermeable vessels; it usually appears of a pale yellow color, of the consistence of cream, and depositing more or less of the solid body according to the time it has been exposed to the air or the heat it acquired in the transport. Caoutchouc juice is miscible with water; but if the solution be heated, it will coagulate owing to the albumen which it contains, the chief part rising in a layer to the surface. Alcohol does not precipitate it from the natural juice, but causes the deposition of the albumen. None of the usual solvents for solid caoutchouc, such as naphtha, caoutchoucin, *et cetera*, are miscible with it. The specific gravity of the juice is 1·012, but that of the coagulated pure substance is only ·925.

To prepare the pure caoutchouc, all that is necessary is to mix the juice with four or five times its bulk of water, allow it to stand for twenty-four hours, and then heat; the caoutchouc rises to the surface in a layer which is to be skimmed off; and the operation repeated once or twice, as long as anything is extracted. The gum is then pressed between folds of cloth. Sometimes it is precipitated from the aqueous solution by the addition of common salt, or of hydrochloric acid, to the liquor, which helps to free it more thoroughly from the accompanying impurities.

Thus prepared, it is a white opaque body; but, after drying, it becomes transparent. Water, whether hot or cold, has no solvent action upon it; by long boiling in this liquor, however, it softens and swells to some extent, in which state it is affected by various menstrua with greater facility than in its ordinary condition. But if the caoutchouc be exposed to the air for some time, it resumes its original form. Ether, washed with water to remove all traces of alcohol, dissolves it in moderate quantity; but alcohol precipitates the caoutchouc from this solution. On evaporating the ethereal liquid, the substance is obtained unaltered, only that the surface has the property of adhering firmly, like that of a sheet newly cut. Many volatile oils—naphtha in the cold—dissolve caoutchouc; it would seem that only a portion of that which is taken up by these liquids is really dissolved, the rest being only greatly distended. Camphene holding about three per cent. of sulphur, is said to be a good solvent for this substance; so also are the fat oils; but when its solution in the latter is evaporated, the caoutchouc remains in an adhesive state devoid of elasticity. Linseed and a few other fixed oils dissolve this body, forming a varnish which, Ure and Parnell state, has not the property of depositing the caoutchouc on exposure to the air.

According to Booth, linseed oil has no effect upon it; neither has the oil of lavender the power of dissolving it, which Ure affirms. Oil of turpentine dissolves it freely, and the solution leaves, on exposure, the caoutchouc possessing all its natural properties, so that the turpentine varnish may be applied to all the uses which the native juice is made to serve. Bisulphide of carbon dissolves about one-twentieth of its weight of the elastic gum, and leaves it, like the oil of turpentine, on evaporation, possessing its elasticity and other properties. Benzol ranks among its best solvents, as also caoutchoucin, a liquid hydrocarbon, procured by subjecting the ordinary bottle caoutchouc to destructive distillation, and which will be referred to more in detail further on.

At ordinary temperatures the concentrated mineral acids have scarcely any action upon india-rubber. Sulphuric acid slightly carbonizes it on the surface in the cold, but if heat be supplied it is entirely decomposed, carbonic and sulphurous acids resulting. It is decomposed by nitric acid also, especially when aided by heat, being converted into carbonic and oxalic acids, while nitrogen and nitric oxide are evolved. Alkaline lies have but very little effect upon it in the cold; by long digestion, however, in the heat it becomes soft and glutinous, and dissolves in small quantities. Gases, such as chlorine, sulphurous acid, and fluo-silicic acid, have no action upon it; but nitrous acid vapor readily attacks it. Ammonia, after a contact prolonged several months, seems to exert the curious influence of bringing it back to the state of an emulsion, in which form it may be used as a varnish, as it recovers its peculiar qualities on drying.

Caoutchouc manifests very curious properties on the application of certain degrees of heat and cold.

When the temperature is elevated to about 248° Fahr., it melts and remains in a semifluid adhesive state on cooling; but if exposed to the air in thin layers, it gradually acquires hardness. Heated in the air it smokes, evolves an odor which is not very disagreeable, and burns with a strong yellowish white fuliginous flame. It is made into torches by the natives at Cayenne in Guiana, and other places where it is easily procured. It has been observed, that when a piece of india-rubber is suddenly stretched, it becomes warm and electrically excited. By digesting it in warm water, it may be extended to seven or eight times its original length without having its contractive powers destroyed. Submitted to a temperature near the freezing point of water, caoutchouc becomes hard, loses its elasticity, and appears more opaque than when it is only heated. The same results happen if the substance be retained for a long time in a state of rest; but all the original properties are restored by the application of a moderate degree of warmth. This is a point of great importance in the application of caoutchouc to the manufacture of textile fabrics, as before the threads can be adapted to the preparation of the cloth, they must be deprived of their elasticity. To effect this, they are extended to seven or eight times their original length, and kept at this degree of tension for two or three weeks. The material may then be worked, and, when made into fabric, its elasticity is restored by the application of a gentle heat.

As stated by Ure and others, the caoutchouc, when stretched as above, and suffered to remain in that state for such a length of time as will suffice to destroy its elasticity, increases in density, being, under these circumstances, 0·9487, whereas, when the elasticity is restored by heat, the specific gravity decreases to ·9259. Caoutchouc is shown by Faraday and others to be a hydrocarbon, composed of—

		Centesimally.	
	Atomic weight.	Theory.	Found.
8 Eqs. of carbon, ...	48	87·27	87·2
7 Eqs. of hydrogen, ...	7	12·73	12·8
1 Eq. of caoutchouc, ...	55	100·00	100·0

The natural juice contains a variable amount of caoutchouc, from thirty-one to thirty-seven per cent. A sample of it gave—

	Centesimally.
Water, containing a little free acid	56·37
Caoutchouc,	31·70
Albumen,	1·90
Wax,	a trace.
A nitrogenized body soluble in water,	7·13
A substance insoluble in water,	2·90
	100·00

Dr. URE found, in two samples of the juice, no albumen, though in one there was only twenty per cent. of solid caoutchouc, whilst the other contained thirty-seven per cent. From this fact, he infers that the presence of albumen is not essential to the juice.

MANUFACTURE.—The importance of caoutchouc, or india-rubber, in the industrial arts, is becoming now well appreciated and almost universally known; but great as are the benefits which it already affords to society at large, these cannot fail to be multiplied to a vast extent, as genius aids in the discovery of mechanical and chemical means more adapted for bringing it to the required forms. Already it has been made available to the comforts of life in the shape of woven textures, substitutes for leather, *et cetera*, many of which it supersedes in a great measure in point of durability and resistance to atmospheric influences. It has also, in the shape of the conical buffer, been the means of preserving life and property in the many accidents which happen in the present vast extent of railway travelling and traffic. As a substitute for paper, it answers admirably in many instances, especially as it is capable of receiving white or colored grounds, on which may be impressed more delicate lines of engraving than on the best kind of paper. To the bookbinder it offers very great advantages; and the volumes held together by its means are remarkable for their flexibility and freedom in opening. In decorative arts, and for many scientific uses, it offers great facilities, which, at the present day, could not well be dispensed with. To the chemist it is of paramount importance, enabling him to arrange, at little expense, complex apparatus which, were this not at hand, would require time and expense. In surgery, also, it has a place reserved for its exclusive use, especially in the construction of instruments requiring suppleness and flexibility. In fact, the enumeration of all its applications would be a work of time; and as some of them are rather happy adaptations, than subjects of strictly scientific interest, the Editor will refer in the sequel, as occasion arises, to those only which, from their acknowledged utility, demand to be noticed.

In the preparation of caoutchouc, there are three apparent divisions; or it may be said to consist of three special branches; these are—

1st. The condensation of the crude material imported, and the cutting of this product into pieces or shreds to answer the requirements of the surgeon, stationer, currier, *et cetera*.

2d. The filature of either the india-rubber or the prepared caoutchouc, into tapes or threads of the requisite length or fineness, and which, whether covered or not with silk, cotton, or yarn, form the basis of all elastic tissues.

3d. The conversion of the refuse cuttings, and the inferior quality of caoutchouc, into a kind of varnish, which, being applied between two surfaces of cloth, constitutes the well-known double fabrics impervious to water.

PURIFICATION AND CONDENSATION.—As imported, caoutchouc is always more or less impure, but sometimes it is fraudulently adulterated at the time of its extraction, by interposing clay, sand, resins, and various substances, between the layers as they are dried on the moulds. The first thing which is necessary, on the part of the home manufacturer, is to free it from those matters, and afterwards convert it by suitable means into the various articles intended. This purification is for the most part effected by mechanical means; for nothing short of complete solution of the caoutchouc in a menstruum is found to be effective for its depuration. The substance is usually cut into very thin shreds or minced very minutely, and washed by agitation in warm water, or by passing a stream of the liquid over it, after which it is laid upon iron trays, in a chamber heated by steam, to dry. During the desiccation it is kept carefully stirred, in order to liberate any adhering dirt. After the cleaning in this way, the fragments are again conducted between a pair of iron rollers, under a stream of water, and thus they get a second elutriation, and the several pieces become blended together into a homogeneous sheet. If the materials still retain any heterogeneous mixtures, the sheets are returned to a hopper over the rollers, set one-sixteenth of an inch apart, and passed several times between them.

After the cleansing is concluded, it is subjected to another machine which kneads it into homogeneous masses, expels air and moisture, and gives it a greater density. This machine, which is called the *mill*, consists of a cylindrical box of cast-iron, eight or nine inches in diameter, set on its side and traversed in the line of its horizontal axis by a shaft of wrought-iron furnished with two or three rows of projecting bars, called the kneading arms, placed at an angle of about 120° to each other. These act by rotating against fine chisel-shaped teeth, which stand obliquely up from the under part of the drum or cylinder. The drum consists of two parts; the lower one is firmly set in a metallic framework, and the upper is attached to the preceding at the back by hinges, whilst bolts secure it at the front. It can be opened at pleasure, and the contents examined and extracted if necessary; and a fresh charge of the clippings and fragments can be introduced by means of a funnel fitted to the cover, and through which a stream of water percolates for the purpose of carrying off any foreign matters which may be separated during the kneading. The power required to work one of these mills may be judged from the fact, that if the drum be only two inches in diameter it is readily twisted asunder, and has to be three inches at least in diameter, to withstand every strain produced by the fixed teeth holding the caoutchouc against the revolving arms. Five pounds of the caoutchouc constitute a charge. A very remarkable phenomenon of this milling process is the great evolution of heat, which takes place to such an extent that the stream of cold water admitted to wash the substance is readily brought to the boiling point;

and if water be not supplied, the temperature rises so high as to render it unsafe to touch the mass, notwithstanding that it is a bad conductor of heat. This development of heat must be due to some internal movement of the particles of the mass, as during the kneading its volume is hardly diminished. After this species of washing, the mass of caoutchouc is transferred to another drum, somewhat like the foregoing, where it undergoes a further thorough mixing, by which water and air, taken up in the preceding washing, are expelled from it. In the second drum the agglutinated ball of caoutchouc is exposed to the cutting and indenting action of three sets of chisels, containing five in each set, that project from the revolving shaft at angles of 120° to each other, and which encounter the resistance occasioned by five stationary chisel teeth standing obliquely up from the bottom of the drum. A little quicklime is here commingled with the caoutchouc. As in the former operation, the substances get very hot in a short time, and evolve aqueous vapour, and the air which was confined in interstices within it, escapes through the punctures made by the chisels; the evolution of the latter occasions repeated explosions.

At the termination of this kneading, the ball of caoutchouc is drawn forth much more compact than from the first mill; still, however, it is not in a sufficiently dense state for the various uses to which it is applied. To obtain the proper density, the balls, after undergoing the two preceding operations, are introduced into a third drum, the shaft of which is supplied with flat pressing bars and parallel sharp chisels perpendicular to it; in this machine the caoutchouc is both compressed and kneaded at the same time. Lastly, to complete the kneading, seven of the balls are introduced into a much larger cylinder, constructed similarly to the forementioned, but much stronger, and having the shaft studded over with a great number of blunt chisels. In this drum all the balls become perfectly incorporated, and the mass is freed from cells or interstices, and is suitable for being introduced into the rectangular cast-iron moulds, where it is highly compressed by the action of a screw-press. When condensed to the utmost in this box, the lid is secured in its place by screw-bolts, and the mould set aside for several days.

Such is the method followed in the principal caoutchouc factory in London.

Mr. Nickels' mode of operation is not very different from that just described, only that his cylinders are open at the sides and more capacious, and he dispenses with the stream of water, as he laminates and washes the material sufficiently before recomposing it into a homogeneous mass. The kneading is performed in about two hours, and the balls are pressed in moulds of a cheese-like form under an hydraulic machine of seventy tons. This weight is not brought to bear at once upon the mass; but at intervals of two or three minutes the pumps of the machine are worked a few strokes, and when the entire force is exerted the press is locked and retained so till the mass gets cold, after which the attendant removes the pressure, and either turns the mass out of the mould, or raises it while it is being cut into layers of proper thickness by a knife.

Lorimer prepares the pure caoutchouc by reducing the crude material, by means of knives, into very thin shavings, which are dried by spreading them over any convenient surface. After the drying, the bands and filatures are subjected to appropriate machinery, by which they are bent in various directions, and reduced or torn into smaller fragments. By this means, the impurities mechanically united with the rubber are separated and sifted off, and thus the purification is effected without the intervention of heat or water, at a smaller cost than usual.

Cutting into Sheets.—After the kneading and cleansing of the caoutchouc, the squares or round blocks are sliced into sheets, adapted either for the use of the stationer, or for the purpose of making bands or threads.

This is performed by a self-acting machine, in which a straight steel blade, with its edges slanting downwards, is made to vibrate in a horizontal position, while the cake of caoutchouc, held firmly by clamps or other suitable means, is raised regularly against the blade. No matter how keen the edge of the knife which is employed to cut the india-rubber may be, it is necessary that it should be kept wet with water, otherwise the heat produced will be sufficient to melt part of the material upon it; and when this happens, it will be held fast in the mass. The larger slices cut off are afterwards divided into suitable parallelopipeds by the hand, for the convenience of the draughtsman, *et cetera;* and the thinner sheets are reserved for cutting them into bands or threads for the manufacture of various articles.

The knife which cuts the discs of caoutchouc is a circular shears of the same kind as those employed in paper-works. The caoutchouc disc receives two movements depending on that of the shears. A first relative movement permits the disc to turn as the shears cut it; the second is designed to steadily approximate the centre of the caoutchouc disc to the edge of the shears, so that the strip which is cut away may always be of the same thickness. All these motions are dependent on one another, in such a manner that the action of the shears may be increased without changing the result in any respect. This effect is produced by a number of wheels, the diameters of which are calculated beforehand, gearing into each other.

Caoutchouc Thread Manufacture.—When the ribands of caoutchouc are obtained, they are now to be divided into threads of equal thickness. This is performed with great ease by circular cutting edges, similar to those already mentioned, placed on the same axis and kept at the required distance, that is, at a distance from each other equal to the thickness which it is desired to give to the caoutchouc threads. The riband is taken up between the knives, and thus are obtained the threads which are intended to be woven into fabrics.

Sometimes the caoutchouc bottles which are whitest and most uniform in texture, and possess the greatest degree of elasticity, are used directly for the manufacture of thread, but when much impurities are present the caoutchouc must undergo a process of purification similar to that already described. The threads usually manufactured are numbered according to their degree of fineness, being marked from one to eight. A pound weight of the No. 1 thread measures five thousand yards, the same weight of No. 4 being two thousand, and of No. 8 seven hundred yards. Threads made from the bottoms of the bottle india-rubber is said to be much stronger than those cut from the recomposed or *milled* blocks; but it has been found, that if the various operations necessary for the purification of the caoutchouc be properly performed, it affords a filature that answers all the required purposes, and has besides the very material advantage of being lower in price.

Were the threads of caoutchouc to maintain their elasticity, considerable difficulty would, in consequence, be thrown in the way of their being woven into fabrics; but, fortunately, when they are extended to seven or eight times their length and submitted to cold, the particles of the caoutchouc accommodate themselves to the forced position, and remain inelastic. In the manufactory, this result is arrived at by allowing the thread as it is cut to get heated in warm water, after which it is passed through the cold fluid, and then wound upon the reels or bobbins as an attendant stretches it. The persons employed for this purpose—generally boys and girls, and known as the *tenters*—press the thread between their thumb and forefinger moistened with water, and so stretch it to at least eight times its original length, as it is winding up by the power-going reel. Considerable heat is developed in the operation, accompanied by condensation. After the reels are filled they are laid aside in a cold situation for a longer or shorter time, according to the quality of the caoutchouc—the recomposed article requiring a longer time than that made from the bottle variety. After having thus destroyed the elasticity, the thread is wound upon the bobbins of a size suited to the braiding or other machine by which it is woven. Should the thread break in any of these operations, it may be united again by means of the property of the substance of adhering to itself. The broken ends are cut obliquely with clean scissors, and the surfaces of both sections pressed together; a perfect junction is thus formed.

There are two modes of using the caoutchouc thread; the most ancient consists in weaving it round with lace of six or seven others, which completely surround it. The small cord obtained in this manner is used for the manufacture of braces. A newer process, and which presents great advantages in certain cases, consists in covering the caoutchouc thread only in the process of weaving; this arrangement, besides dispensing with the lace-looms, allows of embroidering of the fabric with flowers and ornaments determined by cartoons. In a word, a *Jacquard* loom is employed for weaving, and the filament of caoutchouc is treated as an ordinary one, if it be not an object of importance to conceal it in the manufactured article.

During this period the threads of caoutchouc retain their rigidity, but that elasticity of which they were destroyed is restored by exposing the woven fabric to a temperature of 140° to 160° Fahr., in a stove or heated chamber. At present this is very simply but ingeniously performed, by passing a roller suitably heated over the cloth, when the caoutchouc threads resume their original extent. Whilst the cloth is being thus heated, it shrinks in length without acquiring any extra width; by this means the texture is compressed and retained in this state as long as the chain of caoutchouc remains elastic.

MANUFACTURE OF ROUND THREAD.—Messrs. AUBERT and GERARD have established at Grenelle, near Paris, a caoutchouc thread manufactory of a new description. Up to the time when the invention of these gentlemen appeared, for preparing the caoutchouc thread required for the manufacture of elastic fabrics, no other method was known than that of cutting mechanically with scissors, either the caoutchouc in bottles, or the same kneaded with essential oil, and made into sheets. This method, still employed in the large manufactories, gives, as may be conceived, flat threads, which are limited both in length and thickness; whilst the process of GERARD and AUBERT produces them perfectly cylindrical, quite unlimited in length, and the size or thickness of which may be varied to any extent.

The caoutchouc arrives at the factory in any condition—in bottles, in sheets, or in waste cuttings; and is immediately divided and purified, or cleaned, as above described. After this operation comes the conversion into paste, or what may be termed the chemical process. For this purpose, the caoutchouc, previously reduced by the rollers to a shred, is divided into small strips, which are introduced by hand into zinc boxes with wide openings; over the caoutchouc is poured in the box sulphide of carbon, not pure, but containing about five per cent. of alcohol. The proper quantity to use is double the weight of the caoutchouc—a little more or a little less, according to the quality of the gum. This being done, the lid of the box is adjusted, fitting into a very deep groove, packed with tow, impregnated with a mixture of glue and treacle, or some other soft and humid substance, forming a kind of cement impermeable to the sulphide of carbon. After macerating in the liquid twelve or fifteen hours, the caoutchouc is ready to use; it is not dissolved, however, as might be expected, but is merely softened so as to resemble flour paste, and may be kneaded in the same manner.

The caoutchouc paste is introduced into vertical cylinders, the lower end of which is fitted with wire gauze, and in these, by means of a piston and pressure, it is sifted or strained repeatedly, to clean it and knead it thoroughly; it is then put into another vertical cylinder, somewhat similar to those which are used by the vermicelli-makers. The elastic matter, forced through by the piston, comes out in threads through small holes placed in a single row, in order that they may not overlie each other—a precaution that is not required in the making of vermicelli. The threads are received on an endless web of velvet in motion, and traverse in this way a course of thirteen feet; they are then taken up by a web of common cloth, which passes over a space of five hundred to six hundred and sixty feet in about ten minutes. At the end of this journey they are sufficiently dried; the solvent is in great measure separated; the threads then quit the web, and are received into channels or grooves, which conduct them into small cups disposed in seven rows, in such manner that each one has its own particular cup. When the cups are full the filament is taken out, and is left for some days exposed to the action of the air.

The threads produced by pressure have any required thickness, and this may be made to vary at pleasure. Experience has shown that a thickness of ·0394 of an inch is preferable for regular work, but these do not suffice for all kinds of fabrics; in a great number of cases they must be used finer. For this purpose annealing is resorted to. The caoutchouc being drawn out, and exposed to a temperature of 239° Fahr., no longer shrinks, but retains the length it has acquired, and moreover may even be drawn out anew. By thus stretching and annealing it successively, a thread of caoutchouc may be brought to a degree of fineness limited only by the dexterity of the workman, and may, for example, be represented by a length of ninety-eight thousand four hundred feet to 2,205 pounds.

The thread thus obtained is of common caoutchouc, but nothing is simpler than to make, in the same manner, thread of vulcanized caoutchouc, the nature of which will be described in the sequel; for this purpose, it is only necessary to incorporate the caoutchouc into a paste with flowers of sulphur, and to heat to the temperature of 266° or 284°. Let it be noted in passing, that at the temperature of 239°, necessary for the annealing of the stretched thread, no vulcanization takes place.

The two kinds of filaments, the natural or the vulcanized, are employed in weaving, according to the special object in view: the former of these is wound on bobbins, retaining its maximum extension; deprived of elasticity, it may be worked like any other textile material; its elasticity is restored by passing a hot iron over the fabric. The vulcanized caoutchouc can be employed in weaving only by the aid of a peculiar artifice—it must be kept extended by weights.

Much has been done in the manufacture of elastic fabrics by Messrs. RATIER and GUIBAL in France, where this species of texture is brought to great perfection and used very extensively, from the garter and brace to the elaborately worked bodice. But it seems that what has been done as yet, is only a pathway opened to its more extended use. The results of late years warrant this anticipation; for, laying aside all the other good effected by this article, what it has been made to serve in point of personal comforts, through the exertions of Messrs. MACKINTOSH, GOODYEAR, and others, is enough to elicit the grateful approbation of the community for their meritorious exertions.

WATERPROOF FABRICS.—As the process by which the waterproof clothing is manufactured may be of interest to the reader, the Editor indulges in a short description. These fabrics, which are usually called Mackintoshes, after the inventor, are formed of ordinary cloth, coated on one side with caoutchouc; but sometimes they are made of two fabrics united by an intermediate sheet of caoutchouc. The interposed body being perfect throughout, renders the cloth impervious to water, and hence as over-garments for the purpose of keeping out wet they are unequalled. As, however, perfection in every point is hardly to be expected, and never found in anything of human invention, so neither is the Mackintosh cloth answerable in every requirement. The most serious disadvantage to which the wearing of apparel, made waterproof by coatings of caoutchouc, renders a person liable is, that it intercepts exudation, and causes it to be retained in the under-garments. This is a serious defect, as it lays people open to the danger of colds and the like diseases; and unless by some yet undiscovered means it be removed, it will continue to restrict the use of these fabrics.

To obtain a coating of the caoutchouc sufficiently thin to be imposed upon the fabric, recourse is had to solvents, which liquefy the ordinary substance, and by applying this solution to the surface of the cloth, a film of the caoutchouc is left as the volatile fluid evaporates, and this film acts as an effectual obstruction to the passage of water. The solvents usually resorted to are ether, sulphide of carbon, naphtha and crude petroleum, benzol, spirit of turpentine, and the essential oil obtained from the distillation of the crude material; but that most frequently used is the spirit of turpentine. Most of these solvents, especially the latter and naphtha, communicate their peculiar odor to the cloth, in consequence of a portion of them being obstinately retained by the layer of solid material, and which, besides imparting to it a disagreeable smell, to some extent softens it. Although a great many ways have been suggested for disinfecting waterproof cloth, and for the preparation of varnishes, yet in this department there remains ample room for research and improvement. Apparently, the facts to be sought are, not how caoutchouc can best be dissolved in essential oils, for these cannot afterwards be wholly eliminated, but how it can be brought back to the state of an emulsion, such as it was when exuding from the tree. There is little doubt that, for the fabrication of waterproof clothing and other requisites, the emulsion would admirably answer all the required ends; and thus, could it be conveniently imported, the expenses of the spiritous liquors and labor now laid out upon preparing the varnish would be unnecessary. Much difficulty, however, stands in the way of transporting the liquid to England; for, besides the expense of carriage being greater, the least exposure to the air may coagulate it, and consequently defeat the end for which the expense of vessels for its reception, together with the cost of carriage, has been incurred.

DUMAS suggests, that instead of importing the natural juice, a solution of the solid body in ether might be effected, and the caoutchouc precipitated from this liquid by alcohol. Were this precipitate spread out upon the surface of a piece of stuff and then covered by another, the whole being carefully pressed together by a hot roller, he says that there would be formed, doubtless, a waterproof clothing and quite inodorous. Further, he intimates that if the ethereal liquor were directed upon a hot cylinder, a thin web of caoutchouc would be obtained, which could be turned to advantage by interposing it between two stuffs and uniting them by pressure, whilst the volatilized ether might be conducted back to the liquefying vat, to act upon a fresh quantity of the material without much loss being sustained.

Only the worst kind of caoutchouc is used in this manufacture, and the parings and other refuse matter from the kneading mills already referred to, are turned to advantage. These substances are introduced into a suitable vessel, and the proper proportion of naphtha, oil of turpentine, or caoutchicin added, for the purpose of dissolving it, and the whole allowed to remain till the caoutchouc softens and intumesces, when the solution is accelerated by mechanical contrivances. Preference is generally given to oil of turpentine, after it is well rectified; but it is usual to mix some other essence with it, in order to neutralize or conceal the odor which this oil communicates. The cylinders employed are four feet in diameter and the same in depth, in each of which revolves a vertical shaft four inches in diameter, and making sixty revolutions per minute. Thirteen hundredweight of the caoutchouc forms the usual charge, and before the process of solution, or rather maceration, is completed, three days elapse. According to the consistency of the varnish, which of course is dependent upon the species of goods to be made, the proportion of solvent is regulated, but in every case considerably less than the weight of the caoutchouc is taken.

The wooden framework or gallery, in which the waterproof cloth is manufactured, should be about fifty yards long, so that there may be plenty of room for extending, airing, and drying the pieces; it should be two yards wide, and not less than five high. According to the usual custom, the cloth is wound round a wooden roller, whence it is drawn upwards and stretched over an iron bar, and thence it is conducted downwards and over the edge of another, fixed horizontally and surmounted by a steel-armed edge of wood, but in such close proximity that only a very narrow slit for the passage of the cloth and varnish is between them. By means of a thumbscrew, the orifice may be widened or narrowed at will by elevating or depressing the superior board. In the course of the piece through these various movements, the attendant besmears it in its downward passage towards the space just described, by means of a wooden spatula, with the varnish sufficiently thickened, so that it will not pass through; and as it enters between the edge of the roller and that of the upper board, and continues its course horizontally along the lowest rails, the coating of varnish becomes equalized. The piece is then laid upon the rollers in the upper part of the shed till it becomes thoroughly dried, after which one or two other coats of the varnish are given to it in the same manner. Double waterproof cloths are made by laying the varnished surfaces of two pieces parallel together, and at that instant passing the compound piece between the wooden rollers; the pressure of the rollers makes the union perfect.

Care must be taken that no creases or other irregularities get into the web, which would injure its appearance; and that side which is intended for the lining is always broader than the outside, to insure the latter being entirely coated. After the union of the two pieces, the double fabric is hung up to dry in a well-ventilated shed, where it is retained for a few days till almost all the smell has disappeared. It is afterwards taken, and the protruding selvages of the lining carefully cut off; they serve to cement the seams of cloaks, coats, and other wearables.

When the varnish is required for more delicate work it is made more carefully, and rendered quite homogeneous by introducing it into a kind of hopper, and allowing it to drop between iron rollers set nearly in contact; here any hard or unrendered parts are crushed and softened, so that when, after this treatment, it is applied to the cloth, it forms an even coating upon it.

GERARD, in 1850, secured, by patent, the right of using alcohol mixed with spirit of turpentine, sulphide of carbon, chloroform, benzol, ether, *et cetera*, in dissolving caoutchouc. According to the patentee, when the alcohol is mixed with either of the above liquids in various proportions, from five to fifty per cent., and the menstruum afterwards used to dissolve the india-rubber, a much more concentrated varnish is obtained than with the spirit *per se.* The method described is to mix the alcohol with the solvent as above, and use the same weight of it as of caoutchouc; but, according to the degree of concentration which the varnish should possess, the quantity of solvent is increased to as much as thirty parts to one of the caoutchouc. After forty-eight hours' contact, the mass is submitted to the usual kneading, provided only small quantities of the solution are employed; but when a large proportion of the liquid is required, then it is merely dissolved by the power of the liquid; the heat that is usually developed during the process becomes useless.

The effect of the alcohol in contributing to the formation of varnish is, that it disintegrates the mass of material, and separates the component particles. It has been shown already that alcohol does not dissolve this substance, and in fact precipitates it from its solution, a property which the patentee has sought to turn to advantage in the preparation of the varnish.

During the period of the swelling of the caoutchouc by the absorption of the solvent, the alcohol gets introduced, and by its action detaches the particles abundantly, and prevents their adhesion as long as it intervenes; when the spirit is evaporated, then they unite and acquire all their original properties as when *en masse.* The varnish thus formed is put on the cloth in the same manner as above described.

Mr. LEE NORRIS, of New York, in 1853, obtained a license in France, for a means for importing the juice in its natural state; this he effects by filtering the liquid emulsion through cloth, and receiving it into a proper tin or glass vessel, and a quantity of strong liquor ammonia in the proportion of sixty grammes, or about two ounces to two pounds and a quarter of the juice added, and the contents of the vessel well agitated. The caoutchouc in this liquid remains, even when exposed to the air, in the same state as when it exuded from the tree. It is next introduced into receptacles, which are hermetically sealed, and then exported. Glass or tin cases are to be preferred to others for this purpose. When well prepared and carefully secured in the bottles, it preserves its fluidity for an indefinite period, and remains of its pure white color, possessing all its peculiar properties. In this state it is far preferable to the smoked material for the fabrication of waterproof cloth, and also for other branches of manufacture. When it is required to construct an original or new article from the emulsion, it is run upon plates of glass or polished metal, on glazed paper, or any other appropriate surface, having the same form and dimensions as that which is intended to be produced, and exposed to a slow and spontaneous evaporation, or to a temperature of 70° to 100° Fahr.

The action of the ammonia in this application is, that it prevents oxidation, first, by forming, as it were, an atmosphere over it, by which the air is in some measure excluded; it also deoxidizes any part which may be on the point of precipitating, and thus brings it back to the original liquid state.

EUGENE DE VARRAC has found that bodies made of caoutchouc, which possess the odor of the essential oils in which the substance may have been dissolved, can be deprived of it completely by immersing them in aromatic essences for some time; and also, that if articles of india-rubber, or fabrics coated with this elastic gum, be exposed in chambers to the vapor of these essences, their disagreeable odor will be removed. The materials which the patentee generally employs are verbena root, lavender, camomile, florentine iris, whorl flowers, and the like: a concentrated extract of these is obtained, and a certain quantity of one of the solutions, or several of them, is used for the bath, in which the goods are immersed for twenty-four hours or longer. When the steam from these aromatics is used to depurate the articles, the flowers or other bodies are made into pastilles and ignited in a confined chamber, or their vapor may be obtained from their extract by evaporating such in a bath supplied for the purpose. Fabrics, *et cetera*, may be deodorized by using substances which are not generally considered aromatics. Such are flowers of sulphur blended with ammonia and alcohol, or chloride of zinc mixed with sulphur or chlorine gas. The former are subjected to heat to bring them into action. Air cushions and matresses are submitted to this process of deodorizing. The smell of ammonia and sulphurous acid is dispersed by exposing the goods to a double current of air for a proper period.

Various other improvements are being made almost daily in this manufacture, of which time alone can test the utility. Meanwhile, another new department of the business will be described: the preparation and application of sulphurized, or, as it is called, *vulcanized caoutchouc.*

VULCANIZED CAOUTCHOUC.—For a considerable period a great difficulty prevented the application of india-rubber to many purposes. When the natural caoutchouc was subjected to cold, it lost its elasticity and became quite rigid, and at high temperatures its surfaces adhered together; but the discovery, laboriously and with unwearied diligence worked out by Mr. GOODYEAR, of America, opened the way for fresh uses dependent upon the new properties which the caoutchouc acquired in his hands. Hence, while Messrs. RATIER and GUIBART, in France, were perfecting means for producing elastic fabrics, and MACKINTOSH, in England, adding the acquisition of waterproof cloth, GOODYEAR in America was indefatigable in bringing it into use as a substitute for leather, and was so far successful as to establish an extensive trade in over-shoes or *galoches*, which, notwithstanding the famed ingenuity of Britain, are imported hither in large quantities annually.

The discovery of Mr. GOODYEAR consisted in combining sulphur with the caoutchouc, in such proportions as rendered it capable of retaining its elasticity at low degrees of temperature, and when the surface of two sheets were pressed together no adhesion followed. His mode of procedure could only be conjectured, for he did not patent his discovery; but not long after the appearance of the vulcanized rubber, Mr. HANCOCK, of Newington, who had been zealously devoted to the subject, found a means of sulphurizing the caoutchouc, so that the product resembled, in every feature and property, that of Mr. GOODYEAR. Much merit is due to Mr. HANCOCK for his solution of the problem, notwithstanding that chemical analysis might have pointed out to him the existence and per-centage of the sulphur and other ingredients in the new combination; for the mixing of the sulphur merely with the elastic body will not suffice to communicate the required properties—it must be afterwards submitted to a certain degree of heat before these are acquired. Mr. HANCOCK patented this process, an act which was imitated by GOODYEAR; and, since then, various patents have been obtained for improvements introduced into this department.

It was thought that the incorporation of lead salts was indispensable, but now it is understood that such bodies only serve to increase the weight and make the rubber more compact.

To vulcanize caoutchouc is not a very difficult operation. It is introduced into the grinding mills, as they are called, with the quantity of sulphur required to communicate the necessary qualities, and here kneaded for some time, during which much heat is developed and combination effected. This mixture, or rather sulphide of caoutchouc—for it must be regarded as a true chemical compound—as yet possesses all the qualities of the ordinary material; it is dissolved by all the menstrua which take up the crude substance; its rigidity returns at low degrees of temperature with the loss of elasticity, *et cetera.* When, however, the compound is heated in close vessels to about 300° Fahr., instead of being decomposed as the natural product would be, it acquires the peculiar properties of being no longer soluble in any of those liquids which dissolved it before, though it seems to combine with them; and under their influence swells to a considerable increase in bulk, but contracts to the original form on evaporating the solvent; it retains its elasticity at low temperatures, and loses its adhesiveness. The latter feature is so marked, that the shavings and other matters cannot be turned to account after it has been modified; and the separation of the sulphur and rubber presents as yet so many difficulties, that it has not been accomplished.

This sulphuration of the caoutchouc may be effected by using compounds which hold sulphur in combination, such as chloride of sulphur, sulphide of carbon, and the like; and patents have been obtained for using these liquids in preference to ordinary flowers, or sulphur precipitate, as they afford a compound that is more homogeneous in composition, than when the combination is brought about by mechanical incorporation. When articles of caoutchouc are immersed for one or two minutes in chloride of sulphur, diluted with thirty or forty times its weight of sulphide of carbon, they acquire, after exposure to the due degree of heat, all the properties of the vulcanized substance; or if the material, after being mixed with the sulphur in the mill, be formed into articles by compression in moulds, and while this force is being exerted it is exposed to the heat of 300° Fahr., the form is permanently retained—it is thus that elastic shoes and such like articles are manufactured.

The apparatus represented in Fig. 295 was patented by Mr. **Hancock** in 1847, and consists of the following parts: A, a metallic chamber, into which the caoutchouc is put to be vulcanized, and covered with the lid, C, surmounted by a valve, K; D, a high-pressure boiler, and E a metallic vessel, which contains a mixture of six parts of volatile sulphide and one of sulphur. One part of sulphur is required for six or eight of caoutchouc.

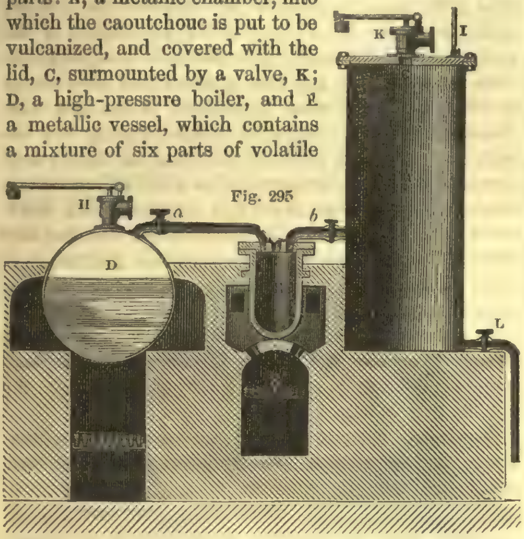


Fig. 295

The furnace of the boiler being lighted, when the safety-valve, H, attached to the latter, indicates 270° Fahr., the furnace, E′, under the vessel, E, is kindled; the stopcocks, *a* and *b*, are opened, and the steam from the boiler, D, first arrives by itself in the chamber, A. A little afterwards the sulphurous vapors escape from the vessel, E, and mix with the steam. After a period varying from half-an-hour to two hours, according to the thickness of the sheets of caoutchouc submitted to the operation, the stopcocks are shut, the fire is subdued or withdrawn, and the valve, K, of the chamber, A, is raised. When this chamber contains no more vapor, the caoutchouc, which is now vulcanized, is taken out.

That the steam and vapors may arrive in A, it is obvious that the pressure on H must be greater than the pressure on A. I denotes a thermometer, and L a tube at the bottom of the vessel, by which the condensed water escapes.

The sheets or webs thus prepared, are rubbed with a dry mixture of sulphide and sulphur, and then submitted to the action of steam at 270° or 300° Fahr. After being rubbed again in the same manner, they are further submitted in the apparatus to sulphurous vapors or the action of steam. Lastly, a paste is spread over them, compounded of sulphide, sulphur, and caoutchouc, in a state of solution, and they are submitted to steam at 270°, or even to a repetition of the same operation.

As experience and observation ripened in regard to vulcanized caoutchouc, the defects which it carried with it were noted, and, time after time, improvements have been made to overcome them. One of these, patented by Mr. **Burke**, proposes to prevent the efflorescence of sulphur, and the offensive odor which succeeded, consequent on its decomposition. He employs sulphide of antimony, and treats it with carbonates of the alkalies at a boiling temperature, decomposing the whole by an acid, by which he produces kermes mineral. The precipitate is well washed and then mixed with the caoutchouc, and sometimes with a mixture of caoutchouc and gutta-percha, according to the elasticity required in the product. The combination is effected in the usual way, and a heat of 250° to 280° Fahr. is afterwards applied. The weight of the antimonial compound employed varies from five to fifteen pounds, being dependent upon the strength and elasticity which are required in the material. The kneading in the cylinders continues about two hours, at the termination of which, and while the substance is still warm, he introduces it into a mould, and applies pressure, which is continued for two days. At the end of this period the blocks of prepared material are taken from the moulds, and exposed to steam for about two hours, after which they are cut into sheets, for the purpose of being afterwards divided into threads, or any other intended use.

Nickels, who took out a patent in 1849, kneads the sulphur in the state of flowers with the caoutchouc, the proportions used being ten pounds of the former to sixty of the latter, and then applies pressure in moulds. He prefers to treat the substance during the kneading with fumes of sulphur, or gases containing it, so as to effect the combination in the cylinder. The sulphur vapor is generated in a still for the purpose, and conducted into the cylinder, which is heated by a steam jacket by a proper conduit. Other gases, such as hydrogen and phosphorus, are occasionally introduced. After sufficient sulphur has combined with the caoutchouc, it is exposed to the compression of hydraulic machines in the moulds, which are heated during the time to 220° or 250° Fahr. To diffuse the sulphur equally through the masses, they are made to undergo a kind of rolling motion under heavy machinery, which is said to have the proper effect.

Many other patents have been obtained for incorporating various substances, such as pipe-clay, silicate of magnesia, ground porcelain, and the like, in different proportions with the caoutchouc, for the purpose of giving it greater body for the intended appliances, as when it is used as a substitute for leather in the various departments wherein it may now be found. Mr. **Goodyear**, by mixing the caoutchouc with magnesia, brings it to that state of rigidity, that it may be employed in the manufacture of buttons, for knife handles, as a veneering for furniture, as a substitute for slates used in schools, and for other purposes. It is also made into various ornaments, such as picture frames, and is now extensively used in the manufacture of combs, braces, belts, harness, saddle girths, flexible gas tubes, hats, boots, shoes, noiseless carriage wheels, *et cetera*.

Mr. **MOULTON** has lately introduced another improvement in the manufacture of vulcanized india-rubber, whereby he can prepare various bodies devoid of smell, and without their elasticity being affected by either heat or cold; as also articles which require much hardness and tenacity.

In the first case, after the caoutchouc has been thoroughly cleaned from all foreign impurities, he submits it to the action of rotatory cylinders heated by steam, and afterwards incorporates in the ordinary way with every pound weight of the substance, from one to ten ounces of hyposulphite of lead, and artificial sulphide of that metal: one of these will answer the purpose, but the patentee prefers the employment of both. In the second instance, when the object is to communicate hardness and tenacity, from two to four ounces of magnesia, or the carbonate of this earth, with the forementioned lead salts, are mixed with every pound weight of the caoutchouc.

After this operation, the compound is exposed to the action of different sets of rollers, called the *crushing*, the *softening* or *smoothing*, and the *flattening* or *stretching* rollers, by which it is made into a thin sheet, which, when brought in contact with the cloth that is to be rendered waterproof, and passed between the rollers of the stretching machine, adheres firmly, and renders it impermeable to water. To make the material indifferent to heat or cold, it is necessary to expose it to the action of steam or heated air in a stove of 250° to 300° Fahr.; this temperature, however, is dependent upon the nature of the goods and the quantity of the substance which has to be operated upon.

NEW COMBINATION OF CAOUTCHOUC.—It has often been proposed to combine tars, mineral or vegetal pitch, or the bitumens, with caoutchouc and sulphur, by the aid of heat; but no one, till lately, appears to have succeeded in this operation. The following is the process successfully adopted by Mr. **GOODYEAR**.

The product of coal tar, or the vegetal or mineral pitch which he employs, is obtained by boiling the tar of the gas-works for two hours and a half to three hours, or till it has acquired the consistence of Burgundy pitch, or rather of a soft resin. The watery portions and gaseous matters being thus expelled, the residue has lost its pitchy character, and may be worked with almost the same facility as caoutchouc, without adhering to the utensils.

This residue of coal tar may be used in considerable proportions with the caoutchouc, and thus a great economy attained in the manufacture of the vulcanized material, and the product is applicable to the manufacture of articles in imitation of horn and whalebone; moreover, these products may be combined with white-lead and coloring matters, as is done at present with that description of articles. They may be applied also to the manufacture of coarse waterproof fabrics, in the proportion of two parts of tar to one of caoutchouc, the substances admitting of being brayed and kneaded together in the ordinary manner; only a larger quantity of sulphur is employed than what the caoutchouc will admit of when employed alone in the mixture, with a view to its being vulcanized.

The work of vulcanizing the combined materials is performed by applying a high temperature, exactly as in operating on caoutchouc and sulphur alone.

When it is desired to manufacture articles of a superior quality, less tar is employed; but always a little larger proportion of sulphur than what would be necessary to vulcanize the caoutchouc.

The addition of a large quantity of tar diminishes the elasticity of the india-rubber; and in manufacturing a substance analogous to horn or whalebone, a little more than one part by weight—six to seven per cent.—of sulphur for two of caoutchouc is employed, and heat is applied as in the making of vulcanized caoutchouc; but when tar is added in this manufacture, it is better to have recourse to a dry than a steam heat. In other respects, the articles are submitted to the ordinary vulcanizing process; only, for objects intended to remain hard, the heat is continued about six hours, but merely raising the temperature to 230° Fahr. during the first half hour, sustaining this temperature an hour and a half, and raising it by little and little during the remainder of the time, up to 300° and 320°. The sheets or leaves thus manufactured, may be united and reduced in thickness by passing them between polished cylinders of steel heated to 194° Fahr.; and these sheets, introduced into heated moulds, receive and retain clean, neat, and delicate forms.

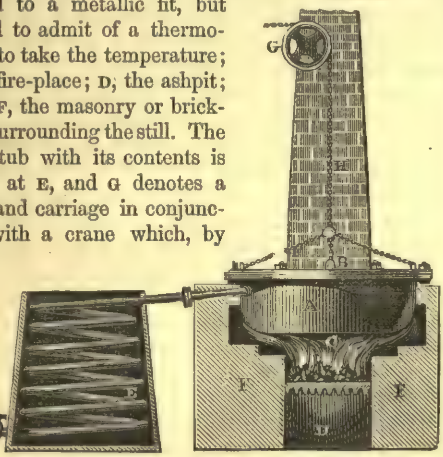
In this description, sulphur alone has been mentioned as producing, by the aid of heat, what is called the alteration of the substance; but all bodies which disengage that element in the heat, may be employed for the same purpose.

Excellent products may be manufactured by rolling together or uniting alternate folds of cloths, or sheets of filamentous materials, with the compound above mentioned—covering over one of the surfaces, or both, with vulcanized caoutchouc, and combining with coloring matters.

DISTILLATION OF CAOUTCHOUC.—When the ordinary crude material is submitted to destructive distillation, it affords a considerable amount of a light carbide of hydrogen, which possesses the property of dissolving the solid india-rubber in considerable quantities. This discovery is said to have originated with Mr. **BERNARD**, while operating with the view of impregnating ropes with caoutchouc. He found that, when this substance was exposed to a temperature of 600° Fahr., it resolved itself into a vapor which, when condensed, possessed the above properties. He secured a license for manufacturing this article in 1833, in the specification of which he says:—A mass of the caoutchouc is taken as imported, and cut into pieces of about two cubic inches; these are thrown into a cast-iron still adapted to the purpose, having condensing media appended; heat is applied in the usual manner, and increased till it reaches about 600° Fahr. As the thermometer ranges progressively upwards to 600°, a dark-colored oil, or liquid, distils over, which is the patented substance. When the thermometer reaches 600°, there will only be left some charcoal, and the extraneous impurities of the crude material. The distillation has been found to be facilitated by the addition of a portion of this oil, either previous or subsequent to rectification, in the proportion of one-third of oil to two-thirds of caoutchouc. The dark-colored liquid thus distilled is afterwards subjected to the ordinary process of rectification, and fluids varying in specific gravity, the lightest of which is not under ·670, are obtained; these are also claimed in the patent. At each rectification the color of the distillate decreases till the density becomes ·680, or thereabouts, when it is colorless and highly volatile. In the process of rectification, about one-third water is put into the still along with the oil, for the purpose of obtaining a larger product of the colorless liquid. Objections have been made to the smell of this fluid; this, however, may be removed by mixing and shaking it with nitro-hydrochloric acid or chlorine, in the proportion of a quarter of a pint of the disinfectant to a gallon of the liquid.

Such is the process followed at the manufactory of Messrs. **Beale** and **Enderby** of London, and Fig. 296 annexed represents the still employed. A is the body, made of cast-iron; B, the cover, ground to a metallic fit, but formed to admit of a thermometer to take the temperature; C, the fire-place; D, the ashpit; and F F, the masonry or brick-work surrounding the still. The worm-tub with its contents is shown at E, and G denotes a roller and carriage in conjunction with a crane which, by means of the chain, H, lifts the cover when the still is to be charged or cleaned.

Fig. 296.



According to the researches of M. **Bouchardat**, the oily product of the distillation of caoutchouc is a very light fluid, transparent, and of a feeble yellow tint. It is so volatile that when the flask containing it is opened, it evaporates abundantly; exposed to a temperature of 4° under zero, it crystallizes in part; but there always remains a pretty considerable proportion of liquid which resists a temperature capable of congealing mercury. By mixing this oil with concentrated sulphuric acid, much heat is developed, a black color is communicated, and a strong odor evolved; if the mixture thus treated be left to rest for some days in a cold situation, a limpid liquid floats on the surface, and which, if decanted and agitated with a solution of potassa and distilled over chloride of calcium at a temperature of 96° to 98° Fahr., affords a limpid colorless liquid of 0·69 at 60°. It boils at 124° Fahr. under a pressure of $0{\cdot}745^{mm}$; it is insoluble in water, soluble in all proportions in anhydrous alcohol; it remains intact when treated with alkalies and acids—in a word, it possesses all the characters of eupion.

The original liquid being heated with much precaution to a temperature not exceeding 50° Fahrenheit, and the vapor being cooled by refrigerant mixtures of snow and chloride of calcium and the like, a liquid is obtained which is no longer solidified by the most powerful frigorific mixtures, and which enters into ebullition before its temperature reaches zero. It is a liquid lighter than the purest eupion, and which may attain the low density of 0·63 at the temperature of 25° Fahr. Water dissolves only an almost inappreciable quantity of it; but it is taken up in all proportions by alcohol and ether. When it is mixed with concentrated sulphuric acid, much heat is disengaged, and the acid is much blackened. On adding water to this mixture, no gases are evolved; but the menstruum becomes cloudy, and deposits a brownish product. After having obtained the preceding carbide, the liquid which distils over between 50° and 64·5° Fahrenheit, crystallizes in the refrigerating mixtures in the form of colorless needles, which constitute *caoutchin* or *caoutchoucin*. They may be separated from the small quantity of water which accompanies them, by pressing them briskly between folds of tissue paper cooled down. These crystals may likewise be obtained with greater facility, by submitting the original liquid to rapid evaporation; the more volatile carbide is thus disengaged, and the cold which it produces by evaporating congeals the caoutchoucin, which is quickly pressed between folds of cooled tissue paper. The caoutchoucin, after being compressed, presents the appearance of a white opaque mass. It melts at 18° Fahr. into a transparent liquid which boils at 58° Fahr., under a pressure of $0{\cdot}752^{mm}$. Its density at the temperature of —28·5° is 0·65. It is insoluble in water, but easily dissolved by alcohol and ether. The alkaline solutions have no action upon it. Concentrated sulphuric acid acts upon it as on the preceding carbide.

M. **Bouchardat** has given the name *heveen* to the less volatile oil which remains after the several rectifications. It is a transparent liquid of a slightly amber color, with not a very marked empyreumatic odor, an oleaginous consistence, and an acrid taste; its boiling point, compared with that of the other products of the distillation, is very high, being about 599° Fahr., and it does not solidify in the most intense cold capable of being produced by frigorific mixtures. Its gravity is 0·921. Like the essential oils, it burns with a thick smoky flame; has neither acid nor basic properties; it is soluble in all proportions in ether, and in anhydrous alcohol; it is much less soluble in dilute spirit, and it dissolves in all proportions in fixed or volatile oils.

It absorbs chlorine with avidity, especially under the influence of solar rays. The liquid thickens much, and ends by taking the consistence of wax, provided the contact is long continued. Bromine and iodine exercise a similar action. Heveen, on being submitted to the action of alkaline solutions, thickens and becomes colored, oxygen being absorbed. With sulphuric acid it gives a blackish pitchy matter, of a resinous appearance, and an oily liquid boiling at 432° Fahr. This liquid is colorless and limpid; it has a sweet odor, is insoluble in water, soluble in all proportions in anhydrous alcohol, and in ether; the concentrated mineral acids, like the alkalies, are without any action upon it; in a word, this body presents the greatest resemblance to eupion, except that it differs from it in its density and boiling point.

Messrs. Beale and Enderby have introduced a compound very serviceable to the shipwright, which they fabricate from the matter left in the retorts after the distillation of the volatile oils, by dissolving it in some of them. It is very useful on account of its resistance to moisture, *et cetera*, and its elastic properties.

A varnish is now prepared from caoutchouc of such astonishing adhesiveness, that masts may be made by splicing the wood together, and joining them with this varnish, no other auxiliary being required to give security; and what is remarkable is the fact, that, when masts, into the formation of which this body has entered, have been broken, the fracture has never been observed to take place where the splice has been, but where the wood was whole.

The glue is formed by dissolving, in about four gallons of coal-tar naphtha well rectified, about a pound of caoutchouc, divided into small fragments. The mixture is well stirred from time to time, till the solution becomes perfect. After ten or twelve days, when the liquid has acquired the consistence of cream, two parts by weight of shell-lac are added to one of this liquid. This mixture is put into an iron vessel, having a discharge-pipe at the bottom, and heat applied. During this operation the whole is kept stirred, and the liquid flowing out of the discharge-pipe in a warm state, is spread out upon slabs, and preserved in the form of plates.

When use is to be made of this glue, it is heated in an iron vessel to the temperature of 248° Fahr., and applied hot with a brush to the surfaces to be joined, taking care to spread it in a uniform layer. The pieces of wood are then brought together, and firmly pressed. If the glue should get hardened before the connection be made, it should again be softened by bringing it to a temperature of 150° Fahr., by passing iron rollers over it, and then the joining quickly made. When the surfaces of contact are well dressed, the inventors apply a thin coating of glue on each; but if there be any irregularities in the wood, the glue should be made sufficiently thick to fill these up. Not only may the glue be used for joining shreds of beams or posts, but also for repairing split pieces. The cracks, or crevices, are filled with the glue while at a heat of 248° Fahr.

Statistics.—The caoutchouc imported in the undermentioned years was as follows:—

	Hundredweights.
1852,	15,269
1853,	19,607
1854,	17,326
1855,	27,588
1856,	44,703

The price of the article varies according to the quality, from sixpence to two shillings and sixpence per pound.

CEMENT.—*Ciment*, French; *Cäment*, German; *Cæmentum*, Latin.—In speaking of cements, attention will be given to the more substantial materials used under that name in architecture, as well as to those employed by the jeweller, the marble mason, the manufacturer of china, and other persons in their respective callings. The term cement is usually applied to such bodies as are capable, by their interposition, of uniting homogeneous and heterogeneous substances. To do this, however, in such a manner as is sometimes observed in bodies that have been cemented, it is evident that a more intimate union must be effected than that of simple adhesion; in fact, that a chemical combination between the components of the cement and those of the bodies to be united, must have taken place; whereas, in other cases, the virtue of the cement lies in its great adhesiveness, by which it excludes air from the broken surfaces. Many of those preparations, into the composition of which resins, gums, and albuminous bodies enter, act by adhesion, while the mineral cements used in architecture behave differently, in consequence of a chemical combination being formed between them and the body of the substance.

Resinous Cements.—Under this head might be included those varnishes or glues which are employed by the joiner or cabinet-maker, but as these may be more fully referred to subsequently, they will not be further noticed in the present article.

Miscellaneous Cements.—A compound for connecting broken pieces of glass or china-ware is known as *diamond cement.* It is prepared by steeping isinglass in water till it swells, and then dissolving it in proof spirit, to which a little gum-resin, gum ammoniacum, or resin mastic, dissolved in the smallest possible quantity of alcohol, is added. Previous to being applied to the fracture, it should be gently heated. It resists moisture to a certain extent. Häule recommends that two parts of shell-lac be dissolved in one part of oil of turpentine, and cast into sticks. The same may be employed instead of glue, by dissolving it in spirit, and evaporating to the consistence of a sirup.

Keller gives the following formula for the preparation of a cement for the same purposes:—Two parts of finely-chopped fish glue are steeped for twenty-four hours in sixteen parts of water, then boiled till the liquor is reduced to eight, eight parts of alcohol added, and the whole strained through linen. While still warm, it is mixed with a solution of one part of mastic in nine of alcohol, and half a part of gum ammoniacum in fine powder; the latter is added gradually, and intimately mixed by maceration. When this cement is used, the parts to which it is applied should be heated, allowed to cool, and then covered with the hot fluid and pressed together. In five or six hours it becomes perfectly hard. This cement is not adapted for very porous articles, for which a concentrated solution of shell-lac in spirit of wine answers best. It should be applied to the thoroughly dried surfaces of the parts to be connected.

A very good cement is formed when shell-lac is dissolved in a concentrated solution of borax. Albumen of egg mixed with quicklime makes a very strong cement, but it does not resist water effectually: it is employed to unite pieces of spar and marble ornaments to which moisture has little access. Coppersmiths use a similar compound for securing the edges and rivets of boilers; but in this case blood is substituted for the white of egg. Another variety, very like the foregoing, is prepared by boiling the casein or cheese of skimmed milk in a large quantity of water, and then incorporating the solution with quicklime upon a slab, or in a mortar. This strongly unites fractures of pieces of stoneware.

VARLEY'S CEMENT is made from whiting, resin, and bees'-wax, the proportions being sixteen parts of the first, well dried by heating it to redness, melted with sixteen of black resin and one of the wax, the whole being stirred well during the fusion.

An excellent cement, known as *Singer's*, for connecting articles of brass and glass, and adapted for constructing philosophical apparatus, consists of five pounds of resin, one of bees'-wax, one of red ochre, and two table spoonfuls of plaster of Paris, all melted together. URE'S formula for a cheaper compound, adapted for joining voltaic plates into wooden troughs, is six pounds of resin, one of red ochre, half a pound of plaster of Paris, and a quarter of linseed oil. The ochre and plaster should be calcined beforehand, and added to the other ingredients while in fusion. A cement nearly colorless is obtained from white wax, resin, and a little Canada balsam. Jewellers sometimes use only resin mastic to set, by heat, cameos of white enamel or colored glass to a real stone, as a ground to produce the appearance of an onyx. Mastic is likewise used to connect false backs or doublets to stones, to alter their hue. These cements require to be softened by heat before they are applied.

A concrete, which becomes as hard as stone when set, is made from twenty parts of river sand, two parts of litharge, and one of quicklime, well ground with linseed oil into a paste. It is very applicable for repairing broken stones, such as steps of stairs, and the like. A similar composition, in which porcelain clay replaces the sand, is made for coating brick walls, terraces, *et cetera*, and bears the name of mastic. Ordinary asphalt is a cement made from bitumen, chalk, silicious matter, and oil, but this has been already treated in a separate article. Shell-lac and caoutchouc afford a glue of considerable power.—See page 452.

A very good composition for connecting iron pipes is made from iron filings and chloride of ammonium, ground together, and moistened with as much water as will give the mixture a pasty consistence. It was customary to incorporate sulphur as an ingredient, but it did not increase its adhesiveness; this effect being produced from the oxidation of the iron, which causes it to expand and solidify. The best proportions, as recommended by URE, are ninety-nine of filings, and one of the sal-ammoniac. Another preparation of a similar nature is formed by mixing four parts of iron filings, two of potter's clay, and one of pounded potsherds, the whole made into a paste with a concentrated solution of common salt; on drying, it becomes very hard.

BUILDING CEMENTS.—Having thus briefly enumerated the principal cementing materials employed for miscellaneous purposes, attention will now be directed to that more important part of the subject which relates to architecture. In this department, the substances which are commonly known by the term cement, whether hydraulic or otherwise, deserve particular notice, as they contribute to the solidity and durability of the building in a remarkable manner. And being so important, it would be well if the rising architects of the present age devoted more of their studies to the consideration of this subject.

How well do the enduring architectural remains of Egypt, Greece, and Rome, as also many of the edifices of the early and middle ages of our era, testify to the quality of the binding medium employed, having withstood the assaults of time, whilst numerous others of later date have mouldered away, in consequence of this material being imperfect! It has been already stated that the action of hardening, as manifested by some bodies, is due to a chemical as well as a mechanical agency; such is especially the case with mortars, and hence it will be necessary to dwell somewhat in detail upon this subject, commencing with ordinary or common mortar. But, as introductory to this, it may be proper, in the first place, to say a few words upon the principal component in cement—the lime, and to give a short description of the manner in which it is prepared.

LIME.—The great source of this base is the various chalk and limestone deposits found in the geological formations of every country; but besides these, very large beds of lime salts exist in many other states, and indeed it is met with more or less in all soils, in the ashes of most plants, and also in the bones of animals combined with various acids.

Limestones, and other calcareous rocks, never exist in a pure state; for, besides the carbonate of lime, which is the principal, and nearly the entire ingredient, other substances, such as magnesia, clay, ferruginous and bituminous matters, are contained in them, and from which they obtain their specific names. Only calcareous spar, and a few other minerals, are entirely composed of pure carbonate of lime. Besides the designations *magnesian*, *argillaceous*, *et cetera*, limestones are often named from the peculiarity of their *molecular* arrangement. Thus mineralogists give the appellation of *compact*, *pulverulent*, *chalky*, *lamellar*, *saccharoid*, *granular*, *concreted*, *oolitic*, *et cetera*, to different limestones, according to their respective species.

Ordinary lime may be prepared from most of these; but the facility of so preparing it is greater in some cases than in others, and the lime itself manifests different characteristics. All that is required is to expel the carbonic acid; and heat is the best agent for effecting this. Kilns of various construction are employed, wherein limestones are burned by the agency of peat, wood, or coal, according as the facilities of the locality offer the one or the other in more or less abundance. The proper form of the kiln is a matter of much interest to lime-burners, as a great economy in fuel may be effected by having it of a certain shape; besides that, when properly constructed, it burns much better.

The more common form of kilns exhibits an elliptical section, the upper end being wider than the lower one, wherein is the eye or draft hole. This shape is more advantageous than that of an inverted cone, as some kilns are occasionally constructed, for the former concentrates the heat more towards the top, and therefore the material in this part is acted upon more than it would be if the top or mouth were wider than any other part. Greater facilities are offered for drawing off the burned lime, and the kiln itself is less injured, when the form is elliptical or oval.

But where large supplies of lime are required, these comparatively rude forms are laid aside altogether, and a more scientific construction is adopted. One of the most effectual of these is reported by Mr. Loudon to be that invented by Mr. Booker of Dublin, but since considerably improved. It is composed of two long narrow truncated cones, placed base to base. The height of the kiln is from twenty to thirty feet, the diameter in the middle is seven feet, and it is contracted to three at the top and bottom.

Fig. 297 shows a vertical section of this kiln, and Fig. 298 a transverse vertical cut, showing the position of the shed placed over it. In the first of these, *a* is the side opening to the back of the fuel chamber, which is about two feet square, with iron bars across. On each side of this chamber is an aperture, by which the air is carried to the back, and the entrance of these to the fire is shown at *a* above. The top of the kiln is arched over, the arch springing from *b*. The kiln is fed through the apertures in the arch, and which have cast-iron covers, *c c c*, with lids turning on a pivot appended to them, by means of which the draught is regulated. In Fig. 298 the fuel chamber is shown at *d*, and *e e* are the air-flues between the double doors of the chamber; A is the space where the loading carts stand; *c*, the cast-iron cover of the feeding aperture, and *h*, the cover of the chimney of the kiln shed, B B. This shed over the mouth of the kiln is very beneficial in keeping the materials dry, and heating them more or less before they are admitted into the shaft. C represents the door by which the limestones are conveyed into B B. The kiln is usually built on the face of a steep bank, and is constructed of fire-brick or fire-stone.

Fig. 297.

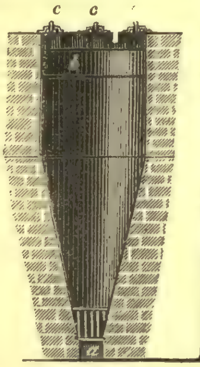
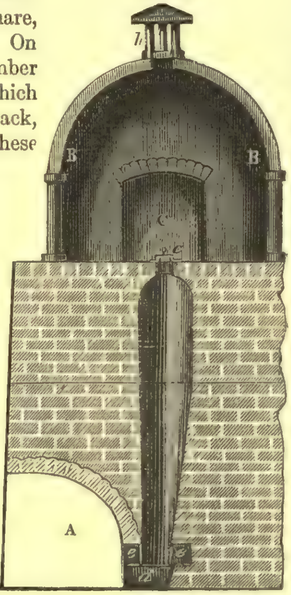
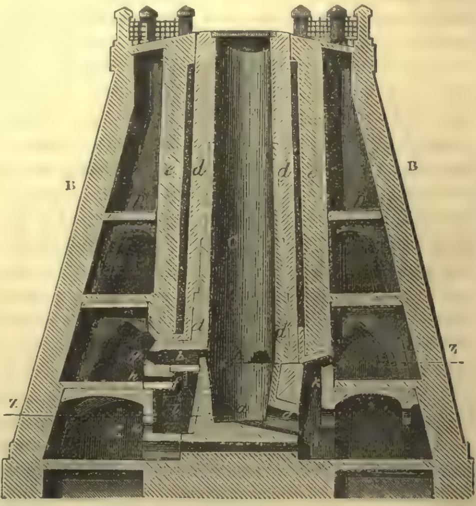


Fig. 298.



As an economiser of fuel, the limekiln of Rudersdorf is the best. Fig. 299 is a vertical section of this kiln, which is heated by wood and peat. The shaft, C, is like the foregoing, formed of two truncated cones, and is about fifty-six Hessian feet in height. It is seven feet in diameter at the top and base, and ten feet in the widest part, opposite where the fires are situated. In the construction of the shaft, limestones may be used in the walls; but that part to which the heat reaches is usually faced with firebrick, the thickness of which increases from half a brick to a brick and a half in thickness as it approaches the seat of the heat. This lining reaches to the height of forty feet, and is shown in the figure at *d′*; the wall being represented by *d d*. All these are encased in an exterior wall, *e e*, built of the same material as *d d*, leaving a space of a few inches in diameter, which is filled with ashes and other non-conducting material. This serves to retain the heat, and likewise to afford room for the expansion of the firebricks and stones which takes place when strongly heated. An outer wall, B B, encloses the whole, and the intermediate space is divided into several compartments by means of arches, *p p p*, which serve as receptacles for the lime, and a temporary domicile for the workmen. The fires for heating the limestones are three, and are seen at *b b*, placed at equal distances from each other. These are arched over, and the arches are lined with firebrick. The grates are composed of two perforated tiles, resting in the middle upon the brickwork, *f*; the perforations in these tiles, by which a current of air, entering by the passage, *h*, is admitted to the fire, are about one inch wide, and three or four in length. *g* is closed by an iron door, as also the outlet from *i*, where the cinders collect at first, and then fall into the channel, E, whence they are cleared off through a door, *z*. These doors are left shut until the space, *i*, is filled, and the cinders have sufficiently cooled to be removed conveniently. The draught-holes where the burnt lime is abstracted are seen at *a a*; these are closed with iron doors, which are luted, except at such times as the content is being taken out, in order that the air may not enter at these orifices to cool the kiln. To facilitate the descent of the lime to these apertures, the sole of the kiln is inclined downwards towards them. As the lime is very hot when drawn, the canal, *k k*, is constructed to afford the men protection from the heat; the canal communicates with

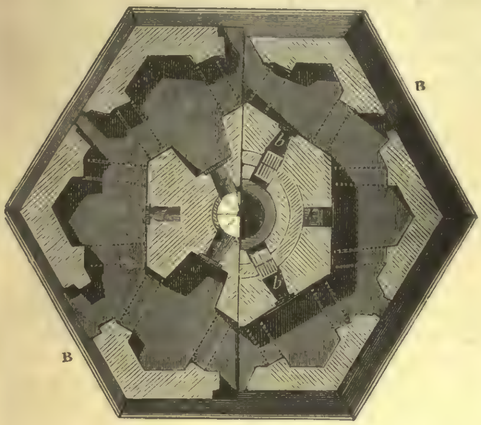
Fig. 299.



the chamber, P, into which the hot air ascends, a current being instituted in this passage by the fires.

Fig. 300 shows the plan of the preceding, at the lines, Z Z, the section being horizontal with the fires, *b b*, on the one side, and with the draught-holes, *a a*, on the other. When the kiln is set in operation, the part of the shaft to the level of the fires is filled with limestone, and fires lighted in *a a a*, which are kept burning till the calcination is completed. A fresh quantity of limestones is now let down by buckets upon that already burned, and continued till the shaft is quite full, when a heap, three or four feet high, is raised over the mouth. The doors at *a a a* being luted on, so as to shut off the draught, the fires are lighted in *b b b*, and kept up constantly. Whenever the upper stones are observed to be well burned, the lime under the level of the fires is drawn out; this causes the top column to fall in, upon which a fresh quantity of limestones is thrown on and piled upon the mouth as before. Thus the work progresses without interruption; the lime, however, is drawn only at periods of twelve hours, when about sixty to seventy-two hundreds, Hessian weight, are abstracted.

Fig. 300.



The time required for burning lime is affected by many causes, such as the size of the stones, their freshness, and density. It is well known that compact limestones are more difficultly burned, than such as are more porous; also, that moisture to some extent facilitates the expulsion of the carbonic acid, even at a lower degree of heat than is required when the limestone is dry. The usual practice of moistening the stones is not so economical as introducing a jet of steam into the kiln; for, in the first case, the heat serves only to evaporate the water before the material can be brought to redness, by which much fuel is wasted; but in the latter, the limestone may be heated to redness, and then the steam admitted, when it will be most serviceable. Where kilns like the one above described are being constantly worked, there is a great saving of fuel effected by them; but it is evident that they are adapted only for such places as require a very large quantity of lime, and where, consequently, they can be kept in operation without intermission. Theoretically, the consumption of fuel in causticising or burning lime, is only one-tenth of the weight of the limestone; but in ordinary practice, five or six times the quantity which theory shows to be sufficient is used; and where lime is burned for agricultural purposes, and attendance is not very regular, even a much larger amount is consumed.

It is evident, therefore, that those who are engaged in these operations would do well to give the subject their best attention. Much care is required of the lime-burner, especially if the material is of an hydraulic nature; for if he allows the temperature to rise higher than what is required to expel the carbonic acid, the lime in consequence loses its property of setting or hardening.

Mortar is a mixture of slaked lime and sand in proper proportions. When this is spread in thin layers between stones or bricks, as in building, it gradually hardens and acquires a great degree of tenacity, combining at the same time with the substance of the brick or stone, so that the whole becomes one perfect solid. The time required to effect this change is long; for although the mortar becomes sufficiently hard, in a few days or weeks, to enable the wall to bear considerable pressure, still it does not acquire the maximum degree of hardness till after the lapse of many years, and even centuries. One of the causes of the durability of old buildings might be attributed to the long period during which the mortar has been exposed to the hardening influence exercised upon it by age; but even this, as is well known, will be ineffectual in bringing the mortar to its greatest power of endurance, unless it be made with the proper admixture of lime, and silicious or other matters.

Lime, alone, is capable of forming a hard cement, but only when interposed between building materials in a very thin stratum. If it be used in masses of considerable thickness, the degree of cohesion which it acquires is very slight, and, therefore, it is in this state almost useless as a cement. The reason why it is not adapted for the purposes here specified when used alone is, that only the portion in contact with the stone or brick adheres with the required firmness, the body of the mortar remaining friable. Were the surfaces of contact sufficiently extensive and regular, then the effect of the thin layer of hydrate of lime would be sufficient to unite the parts, but it is impossible to supply this condition. As, however, it is found that the lime reacts with such bodies as are different from it in composition, especially if they be of a silicious nature, the fact has been taken advantage of, and sand employed from time immemorial to multiply the surface of contact, and bring the whole of the hydrate of lime into active combination, as well with this as with the surfaces of the stones or bricks, and thus the union is more thoroughly accomplished. Another requirement for insuring the solidification of the mortar is the presence of sufficient moisture. If water be not properly supplied, no matter how true the admixture of the other ingredients may be, the mortar will not become firm; if kept in large quantities of this liquid, it will not solidify; and if it be dried as in a stove, it will not form a cement, but remain friable. Exposure to air is likewise necessary to develop all the properties of the mortar.

Bearing these facts in mind, it will be easy for the builder to prepare his mortar or cement, so that it may possess all the requisite qualities. The best material is quartz sand, not very fine. When the sand is very minutely divided, then the matter becomes too dense to admit the air which is necessary for its proper solidification; on the contrary, if it be very coarse, the interstices are too large to be filled up with the lime. A good result is obtained when irregularly-shaped stones are employed, by taking a mixture of coarse and fine sand, for it has been observed that the more irregular the foreign body mixed with the lime, provided the surface of contact is sufficiently extensive, the more binding is it. When the mortar is intended to form a thin coating exteriorly, fine sand is more appropriate.

After ascertaining the materials best suited for the preparation of the mortar, the next step is to proportion them in such a way as to give the best result. This is a work of considerable importance, and any error committed in it cannot be subsequently remedied. As to the quantity of sand which should be taken, much depends upon the quality of the lime; if it be a *fat* lime, that is, if it be devoid of much foreign matters, and fall into a very fine powder in the slaking, it will require about six times the weight of sand; or three or four cubic feet of sand must be added to one of the semifluid milk of lime. Should the lime contain much insoluble matter, or be what is usually known as *poor*, then the volume of sand must be lessened to two, or two and a half cubic feet. As a general rule, the sand should be mixed with as much of the cream as it will take up without increasing its bulk; and the lime should be so finely divided as to form the thinnest possible stratum between the grains of sand, which it should envelop and bind together.

The cause of the setting of mortar was a problem unsolved for a long time; it was thought that the hardening was due to mechanical agency exclusively; now, however, it has been found that this is not the case, and that chemical combination contributes materially to render it firm and durable. Such chemical action is not wholly confined to the formation of carbonate of lime, as was once supposed. Indeed, it has been experimentally proved, that the mortar in the interior parts of the edifice contains, after three hundred years and longer, no carbonate of lime; and that what has remained without otherwise entering into combination with the material of the stone or brick, is still caustic; and, at most, only half an equivalent of carbonic acid is absorbed, producing a basic or subcarbonate of lime, the formula of which is $Ca\,O, C\,O_2, Ca\,O, H\,O$.

Analyses have shown that a silicate of lime is formed, partly from the sand of the mortar, and partly from that of the stone or brick in the building; and the constitution of this body has a considerable influence in blending the material and mortar together so intimately. Besides the generation of carbonate and silicate of lime, there are other changes which play an important part in the solidification of the mortar; such as the crystallization of the hydrate of lime, as the excess of water in it spontaneously evaporates, or is absorbed by the bricks. This hydrate being dissolved in the mixture, and therefore permeating the whole of the mortar, forms very minute crystals, which, though they are brittle and break very readily when they are bent, yet offer great resistance when the force tends to tear them asunder. Hence, if a layer of such crystals be deposited upon surfaces in close proximity, a power tending to separate them will act upon the ends of very short levers, and tend to break the crystal in that direction in which it is calculated to offer the greatest resistance.

Whenever the moisture in the mortar comes in contact with the air on the outside, carbonic acid is absorbed from the atmosphere by the hydrate of lime, giving rise to carbonate of lime, which deposits in a crystalline state, and this offers the same opposition to fracture as the hydrate in the foregoing instance.

The formation of the carbonate continues as long as the mortar retains moisture to dissolve the base and the air has access. Whatever may be the advantages gained from these combinations, they are not sufficient to impart firmness to the material; it is only from the combined influence of the adhesiveness of the mortar to the stone, rendered more intimate by chemical combination, that the full effects are obtained.

Much injury arises to buildings in consequence of impurities being in the materials of the mortar, more especially if they consist of humus, nitrogenous matters, or alkaline chlorides. When these are present, they produce, by their decomposition, deliquescent salts, which attract moisture and occasion obnoxious damps, besides disintegrating the mortar, and, consequently, destroying its cohesive power. Particular observation should therefore be made, as to whether the sands and water employed in making mortar are free from the substances mentioned. When alkaline chlorides are contained in them they undergo decomposition, giving rise to an alkaline carbonate and chloride of calcium, which is a most deliquescent salt. So ready is this interchange, that it was once foolishly proposed as a means for preparing carbonate of soda on a large scale. The humus and nitrogenous matters, when decomposed in the presence of hydrate of lime, produce nitric acid, which, combining with the latter, yields nitrate of lime —also a deliquescent salt—which is observed in the form of an efflorescence.

Incrustations, however, appear on the walls, which are not occasioned by any of the forementioned causes, and, consequently, do not affect the quality of the mortar like those enumerated. They are composed, according to the researches of KUHLMANN, VOGEL, and others, who examined efflorescences of this kind, of sulphate of soda, carbonate of soda, and chloride of sodium, together with carbonate of potassa, and chloride of potassium; they take their rise from the limestone employed containing these bases. Probably the ash from the fuel used in burning the lime contributes more or less to their formation.

HYDRAULIC CEMENTS.—The common material just described is quite unadapted for many works which have been carried on extensively of late years, such as the erection of docks, dams, lighthouses, and the like, in connection with large trading ports, and coasts dangerous to shipping. For such operations another variety of mortar is used, which has the property of solidifying under water, and hence has been called *hydraulic.* To this mortar, or cement, a few remarks will now be devoted. On account of the special adaptability of some species of limestones for this purpose, they are called hydraulic. Such are those calcareous rocks which contain on an average ten or more per cent. of insoluble matters. When these limestones are burned, they comport themselves differently to the ordinary fat lime, inasmuch as they are very slowly slaked, and if the powder thus produced be made into a dough with water, it very soon concretes into a mass as hard as a rock, and remains unaffected by that liquid. The cause of the hardening of hydraulic cements is to be attributed more to chemical combinations than anything else; it will therefore be necessary to notice more in detail the constitution of those stones which afford a hydraulic lime by calcination, in order to trace their distinguishing quality to its proper source. With this view the following analyses of a few hydraulic limestones are transcribed.

The fresh limestones contain in one hundred parts—

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Carbonate of lime,	89·0	82·5	80·0	79·2	76·5	83·40	79·16	86·87	82·82
,, magnesia,	2·0	4·1	1·0	2·5	3·0			3·90	3·76
,, protoxide of iron,	—	—	—	6·0	3·0			—	—
,, protoxide of manganese,	—	—	—	—	1·5	0·90	—	—	—
Silica,	9·0	13·4	17·0	6·5	11·6	13·97	19·14	5·00	11·76
Alumina,			1·0	3·8	3·6			4·23	
Oxide of iron,			—	—	—	1·73	1·70		1·66
Carbon,			—	2·0	—	—	—		
Water,	—	—	1·0	—	—	—	—	—	—
Loss,	—	—	—	—	0·8	—	—	—	—
	100·0	100·0	100·0	100·0	100·0	100·00	100·00	100·00	100·00

The lime obtained by burning the above, contained in one hundred parts—

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Lime,	82·0	79·3	70·0	74·0	68·3	Undetermined.			
Magnesia,	1·5	3·5	1·0	2·0	2·0				
Clay,	16·5	16·7	29·0	17·0	24·0				
Oxide of iron,	—	—	—	7·0	5·7				
Loss,	—	0·5	—	—	—				
	100·0	100·0	100·0	100·0	100·0				

No. 1 is a limestone from the Jura mountains; it is of a light-grey color, but varies in appearance.

No. 2. Limestone from Nismes; it is yellowish-grey, and is very highly prized as hydraulic lime.

No. 3. This is a marly substance from Senonches; it is disintegrated by water in the ordinary state. Silica remains unaffected when the stone is digested in hydrochloric acid; but it is completely dissolved in caustic potassa.

No. 4 is a dense limestone of unknown origin.

No. 5. A limestone from Metz; it is dense, exhibits an earthy fracture, and is of a bluish-grey color.

No. 6 is a limestone marl from Blankenstein.

No. 7 is from Helbigsdorf, near Freiberg; and

Nos. 8 and 9 are two samples of excellent hydraulic limestones from the Halkin Mountain, Holywell, Flintshire, analysed by the Editor; they have a compact grain, and a dull grey color. These limestones were employed in the construction of the Birkenhead docks, besides being extensively used in the construction of docks, piers, *et cetera*, in other parts of the United Kingdom. The mortar obtained from these stones sets rapidly, and so firmly that the work becomes one solid mass.

The materials are shipped on the Dee and landed in Liverpool at a cost of seven shillings and threepence per the twenty hundredweight; the expense of burning and carriage, *et cetera*, amounts to eighteen shillings and eightpence per ton. From two to five parts of sand from the Mersey are employed to one of the lime; and the mortar which is produced sells from nine shillings and sixpence to half-a-guinea per the cubic yard. Grouting is made to a large extent from the same components.

	1.	2.	3.	4.	5.	6.
Carbonate of lime,	67·86	66·99	49·06	76·82	62·47	39·72
,, magnesia,	5·62	1·67	29·32	2·81	1·35	28·48
,, protoxide of iron,	3·30	6·95	16·83	3·21	5·85	7·50
Alumina,	—	0·39	—	0·89	0·93	—
Total of the constituents soluble in hydrochloric acid,	76·78	76·00	95·21	83·73	70·60	75·70
Silica,	15·57	16.89	3·35	11·03	20·93	Undetermined.
Alumina,	4·18	4·32	0·86	2·86	7·72	
Oxide of iron,	1·13	1·72	0·43	1·86		
Lime,	0·15	0·05	0·06	0·12	0·12	
Magnesia,	0·57	0·37	0·01	0·05	0·30	
Total constituents insoluble in hydrochloric acid,	21·60	23·35	4·71	15·92	29·07	
Loss,	1·62	0·65	0·08	0·35	0·33	
	100·00	100·00	100·00	100·00	100·00	

The hydraulic quality of lime depends chiefly upon the amount of insoluble matter, the per centage of silica, alumina, magnesia, or iron, which it contains. This residuary matter is often chiefly composed of silica in the soluble modification. In examining hydraulic limestones, it is necessary to direct attention to the composition of this insoluble residue. In the preceding table, drawn up by HERMANN MEYER, this has been more particularly attended to.

No. 1. This is the limestone from Krienberge, near Rudersdörf, Berlin; it occurs below the sand. It belongs to the upper division of the shellstone, and being in a state of great disintegration, cannot be employed as ordinary mortar.

No. 2 consists of limestone nodules from the Isle of Sheppey; it is yellowish-brown, massive, and firm. These nodules are used in England for the manufacture of *Roman cement*, and occur in the London clay, which is a member of the tertiary formation.

No. 3. A limestone belonging to the shell limestone formation, which covers the layer of lead ore at Tarnowitz. It is bluish-grey, massive, and nearly crystalline.

No. 4. Cement-stone from Hausbergen. In the manufacture of cement, this stone is mixed in equal proportions with

No. 5, which is a stone from the same locality, and of a poor nature, disintegrated, dark-bluish grey, and slaty.

No. 6. The stone from which KOCH'S cement is made in Cassel; it is a reddish-yellow, massive, dolomitic marl, from the lower shell limestone.

KUHLMANN has shown that, besides the silica and alumina in hydraulic limestones, other substances previously overlooked in their analyses affect the solidification in a very marked degree. These are the alkalies, which he found in larger proportion in hydraulic than in the ordinary limestone. From this he deduced that the formation of hydraulic limestone was due to the infiltration of a soluble silicate through beds of chalk, by which silica would be retained; and he grounded a means of making cements, and hardening chalk, upon the same principle. His method was to digest the chalk in a solution of an alkaline silicate for a proper period, then to wash with water and dry; the silicic acid unites with the lime, and renders it so hard as not to be scratched by the nail.

Hydraulic limestone, if finely ground in the natural state, does not solidify; but after being well burned, and deprived of its carbonic acid, ground or slaked, and then applied as a mortar or cement, it concretes, forming a mass even harder sometimes than the natural rock. The ignition has another effect, by which the silicates, insoluble before the action of the heat, are so modified as to be decomposed by acids, which separate the silicic acid in the form of a jelly. Whatever of hydraulic limestone is dissolved by acids previous to burning, is such as affords a fat lime when burned and slaked, and the residue is a kind of clay composed of silicates of iron, alumina, magnesia, lime, and alkalies, with a greater or less proportion of uncombined silicic acid. During the burning, the latter is taken up by the lime rendered caustic by the evolution of carbonic acid, and a silicate is produced which is easily attacked by acids. So perfect is this change, that almost the entire of the bases in well-burned hydraulic limestone may be removed from the silica. The interchange may be explained thus:—At first the heat causticises the stone by expelling the carbonic acid, and the base acts upon the silicious matters at a high temperature, so that there is a compound silicate of the lime and other bases produced, which is decomposed by hydrochloric acid.

Again, the caustic lime and the modified silicate react upon each other in the presence of moisture, so as to produce a solid stone-like silicate. In this reaction the water performs an important part; for when lime is mixed with aluminous silicates, these ingredients have little or no action upon each other, unless water be present as a vehicle to bring about an intimate molecular contact. This it does in the mortar during the solidification, by dissolving a portion of the lime, and transferring it to the silicious earth to produce the concrete cement. One great corroboration of this fact is, the necessity which exists of keeping the mortar moistened for some time till it is sufficiently hardened. In this case the change is not owing to the combination of water of hydration, although this may take a part in it; for, were that the case, many silicates which have nearly the same composition would harden under water after being deprived of their combined moisture by ignition; but no such behavior has been observed. The only way in which the water contributes to harden the cement is, by uniting with the silicate which is formed through this medium, and producing therewith a hydrate.

With a limited quantity of water, hydraulic lime at first forms a soft, friable mass; but when afterwards immersed in the liquid, it becomes as hard as stone. The time which various limestones require to harden is very variable, and all of them do not acquire an equal degree of compactness, so much being dependent upon the chemical constitution of the lime, and also upon the treatment which it receives. Some varieties solidify in the course of a few hours, whilst others require a period of thirty days before they acquire any very great degree of hardness or of binding power.

Hydraulic limestones are found in almost every country. Those in which the insoluble matters amount to about ten or twelve per cent. afford a cement, the hardening qualities of which are not very great, neither are they readily developed; but when the insoluble matters reach to twenty or twenty-five, or from that to thirty-five per cent., then the substance produced has the qualities required in a very marked degree, and manifests them in a short time, varying from a few hours to three or more days. Although a limestone may be so composed as to be capable of producing a good mortar under proper treatment, yet, when improperly calcined, many, if not all the qualities of the stone may be lost. The burning of the limestone then, which is the chief operation, should be carefully studied, and the temperature regulated with regard to the known composition of the stone; for if the heat applied be too low, the decomposition of the silicious matters will be only imperfectly effected, whilst, if the heat be so great as to cause a semi-vitrification of those constituents, the qualities of the cement will be entirely lost, for those parts will either not slake, or else the whole of the silica will become so entirely saturated with the bases, that no combination will take place when the lime is slaked and made into mortar.

VICAT, who has studied this subject with considerable perseverance, has drawn up a variety of interesting details concerning the effect of heat, *et cetera*, upon hydraulic limestones; and from which the annexed particulars are transcribed. In this table, the figures denote the period that elapsed till the cement hardened, which varied according to the amount of carbonic acid contained in it. Thus, when it contained—centesimally—

Carbonic.	30	27	25	23	20	10
The mortar hardened in	15 minutes.	12 minutes.	7 minutes.	9 days.	30 days.	9 days.

The several samples of cement upon which these experiments were performed, were obtained from the same variety of limestone.

Hydraulic lime scarcely ever hardens on the first application of water, but only acquires a certain degree of consistence, and then gradually becomes more solid.

As the composition of the cements stands in close relation to the degree of hardness which they assume, it may be well to notice shortly each of the constituents, pointing out at the same time the manner in which they tend to solidify the material.

SILICIC ACID.—Of all the components of cements, except the lime alone, this body is the most important, as the hardening depends upon it. It is met with in two states in rocks and minerals, namely, in the crystalline and the amorphous. Rock-crystal, quartz, the diamond, and many other bodies, contain it in the first condition, whilst opal, flints, and similar compounds, contain the amorphous variety. In the crystallized state, silicic acid has very little tendency to act chemically upon bodies in the humid way; but if it be heated to redness with caustic lime or an alkali, then it is brought to the allotropic state, and becomes capable of forming combinations with those bodies. Quartz sand, when mixed with lime, has little value in producing a cement; but if it be first heated with a third of its weight of that base, and then mixed, a considerable difference will be observed in the product. On the contrary, powdered opal, and even precipitated silicic acid, form a tolerably good cement with lime, without heat being applied. It is well known that silicic acid, when freshly precipitated, removes a considerable quantity, if not all of the lime, from its solution in water, a silicate being formed. Such also may be the change which is effected during the hardening of the cements. An excess of silica in the mortar is not, however, desirable, as it does not contribute to its solidity or hardness as much as might at first be supposed; an instance of this fact is, that pitch and pumice-stone, which contain from seventy to eighty per cent. of silicic acid, do not make so good cements as opal.

ALUMINA.—Although, in the form of clay, or a compound silicate with lime, such as probably exists in the mortar, this earth undoubtedly contributes to the hardening of the cement, yet it is not a good agent, nor is much of the hardening to be ascribed to it. In proof of this it may be stated that lime has no action upon cyanite, either in the ordinary state, or when it is calcined, although it contains about fifty-four per cent. of alumina, combined with silicic acid.

CLAYS.—The clays may be used as substitutes for silicic acid in hydraulic mortars, but being very variable in constitution, it is probable that they operate differently in many samples. To make them as serviceable as possible, they ought to be well burned, as by this treatment their union with lime is greatly facilitated. Many clays, before they will form good cements, must be heated with lime to a very high temperature. This is especially the case with the common ferruginous earths.

MAGNESIA.—When minerals, chiefly composed of silicate of magnesia, are brought in contact with lime, they have no tendency to unite, and, therefore, they form no cement. If, however, the magnesia is present in excess, as in dolomite, then it contributes to the formation of a powerful mortar. This behavior of the magnesia is owing to the great affinity which exists between it and silica. In the first case, where the lime and natural silicate of magnesia are brought into contact, there is no combination, because the silicic acid is united more energetically with the magnesia than it could be with the lime, and, therefore, no chemical change is produced which might give rise to a silicate of lime when the powder mass is mixed with water. But in the case where there is an excess of magnesia, not combined in the natural state with the silicic acid, then, on slaking such, the magnesia and silica rapidly unite, and a very firm compound results. Indeed, so powerful is the affinity of silica for magnesia, that the dolomitic limestones always afford a better and more binding compound than if all the base were lime. Dolomites containing only carbonates of lime and magnesia, after being burned, will yield, on being treated with water, a mortar that sets in this liquid; and if silicic acid be present in the proportion of six or ten per cent. or more, a very superior compound results from the formation of a double silicate of magnesia and lime. Hence, when magnesia is one of the components of the hydraulic lime, and is not combined with the silica in the natural state, the setting of the mortar is afterwards to be attributed in a great measure to this body. The degree of compactness which the mortar assumes is, however, to some extent dependent upon the molecular state of the silica, and also upon the amount of the bases combined with it.

ALKALIES.—The alkalies undoubtedly play an important part in giving rise to insoluble silicates during the solidification of the cements. **KUHLMANN** and others have shown that such minerals as contain alkaline silicates, part with the whole of the alkali to water, after they have been subjected to heat for some time. This is more especially the case if the minerals should contain much lime, as then a silicate of lime and a carbonate or caustic alkali result. It has been observed that many hydraulic limestones containing alkaline silicates, communicate an alkaline reaction and a saponaceous feel to the water surrounding the mortar during its setting. It was on this principle of double decomposition being produced by the alkaline silicate, that the above-mentioned chemist recommended the fusion of a quantity of alkali with the inferior varieties of hydraulic lime, for the purpose of enhancing their value. During his investigations on this subject, he observed that there was a larger amount of alkalies present in limestone than was anticipated, and that they had been overlooked in analyses generally, as iodine and bromine were in many waters. He found that a solution of silicate of soda—soluble glass—when filtered through hydrate of lime, loses a portion of its acid, this being taken up by the lime and producing a silicate. The same effect results if sulphate or carbonate of lime be used instead of the hydrate; and if these compounds be taken in large pieces, and immersed in a solution of soluble glass for some time, their surfaces will become so hard from the silicate of lime formed upon them, that they can be highly polished. The depth to which the silicic acid is absorbed is greater according as the immersion is prolonged, till, ultimately, the chalk becomes as hard as stone, being converted into a silicate of the base. From this deportment of the alkaline silicates, it is evident they serve a very important purpose, by yielding their acid to the lime during the setting of the mortar.

Although it will be seen that only the sand, the lime, the magnesia, and a few other substances, take an active part in the solidification, yet the remaining constituents cannot well be said to be inactive; for notwithstanding that the bodies mentioned manifest their action in a striking manner, still, in the course of time, the latter must have some influence in favoring the binding qualities of the cements.

Having thus explained the nature of hydraulic cements, whereby their properties and adaptation to building purposes may be ascertained according to chemical principles, it may now be desirable to allude cursorily to those physical observations from which a good estimation of the value of cements may be formed.

The limestone being burned, with the precautions pointed out in the preceding, it is slaked, and in this process a good idea of its value as a cement may be obtained. If the material contains but very little insoluble matters, or, in other words, if it be a rich lime, then on immersing it for a few seconds in water, and depositing it upon a trough or other vessel, it will immediately disintegrate more or less, produce a hissing noise, generate heat, by which considerable volumes of vapor are evolved, and ultimately fall into a very fine powder. When the lime is poor, on treating it with water, the phenomena observed in the preceding rich lime are not exhibited for five or six minutes; but after this time they begin to be developed with great force.

With lime of very slight or at least of weak hydraulic properties, the slaking does not manifest itself till about a quarter of an hour after the addition of the water, and even then the heat which is evolved is much less than in either of the varieties already mentioned. When the hydraulic properties are more marked, an hour or so may elapse before the lime shows any symptoms of slaking, and then it disintegrates without making any noise, or giving off a hissing sound like the others. If the substance be a very energetic hydraulic, the period of its slaking is very variable, and the usual phenomena are scarcely perceptible. In many cases it cannot be reduced to powder by the action of water, and the heat produced is scarcely sensible to the touch. Those stones which, previous to being burned, consisted almost wholly of carbonate of lime, swell to double their bulk by the action of water upon them after calcination; the poorer kinds of lime increase but very little, or sometimes scarcely at all. If both these limes were disseminated in a sufficient quantity of water, they would be almost entirely dissolved. The other varieties which have *moderate*, *well-marked*, and *energetic* hydraulic properties, increase in bulk not more than the poorer kind just noticed. They set, or harden, on being immersed in water; but in this respect greatly vary. The moderate hydraulics solidify in fifteen or twenty days, and continue to do so for a year, when they have acquired a consistence similar to that of hard soap. Hydraulic limes of well-marked properties set under water in five or six days, their density increasing during a period of six or twelve months. At the end of this time the tenacity is about equal to that of the softer kind of building stone. Water exerts but little action upon them afterwards. The energetic hydraulic limes harden in three or four days after their immersion in water, and in six months they assume the induration of compact limestone, so that they are quite unaffected by the action of a stream of water.

The most important cements in general consumption, are those known as PARKER'S or *Roman*, *Portland*, *Medina*, and ATKINSON'S or *Mulgrave* cements. There are other varieties prepared from plaster of Paris, which are used in many decorations, and are designated KEENE'S, MARTIN'S, *Parian*, *et cetera*.

PARKER'S, or Roman cement, is so called after the similar material which the ancient Romans prepared out of a species of porous rock found in the neighborhood of Puteoli, near Naples, and known at the present as *puzzolana*. This substance, which has been analysed by BERTHIER, whose results are appended, is the product of volcanic eruptions:—

	Centesimally represented
Silica,	44·5
Alumina,	15·0
Lime,	8·8
Magnesia,	4·7
Oxides of iron and titanium,	12·0
Potassa,	1·4
Soda,	4·1
Water,	9·2
Loss,	0·3
	100·0

Another variety of this substance has been recently discovered by SAUVAGE in the Département des Ardennes, which does not present any feature to show its volcanic origin. Its composition, according to the discoverer, is—

	Centesimally represented.
Soluble silica—gelatinous	56·0
Clay,	7·0
Fine quartz sand,	17·0
Fine grey limestone—chlorite,	12·0
Water,	8·0
	100·0

This species occurs below the chalk, resting upon a fossiliferous deposit of clay; it is very soft, and has a pale, greenish color.

As the Romans extended their sway Westward into Germany, they soon found deposits of material similar to that at Puteoli, and to which the name *tarras* or *trass* has been given. So extensive are the beds of this material near Bonn, that the quarries opened there by the Romans have been worked ever since, and the product transmitted to all parts of the country. It is of volcanic origin like puzzolana, and gives indications of being thrown out by the burning mountains of Eifel. A sample of trass from Brohlthal, afforded to ELSNER the annexed numbers:—

	Centesimally represented.	
Silica,	11·50	
Oxide of iron and traces of manganese,	11·77	
Alumina,	17·70	
Lime,	3·16	
Magnesia,	2·15	
Potassa,	0·29	
Soda,	2·44	
		49·01
Silica,	37·44	
Alumina,	1·25	
Oxide of iron,	0·57	
Lime,	2·25	
Magnesia,	0·27	
Potassa,	0·08	
Soda,	1·12	
		42·98
Water with traces of ammonia,		7·65
Loss,		0·36
		100·00

Trass and puzzolana are admirably adapted for the manufacture of cements of hydraulic properties; for, as will be seen by the preceding analyses, they contain a large quantity of amorphous silica which combines with the lime, as well as considerable quantities of alumina and iron which also enter into combination; and besides, the large amount of the alkalies present in them contributes materially, as has been already shown, to set the compound in water. Both these varieties are generally ground by stamping mills to a very fine powder, and then exported. It was for a substitute for this material that Mr. PARKER obtained a patent about fifty-eight years ago, to produce the *Roman cement.* The substances employed by him were such as still continue to be the basis of this material; they are nodules of an ovoidal or globular form found in the London clay, and known by the term *septaria.* It was thought that these nodules were confined to the few places in which they were then discovered; but as the search for them became more general, they were detected in the Isles of Wight and Sheppey, and also on the coasts of Kent, Somerset, and Yorkshire, as well as on the coast of France. PARKER's procedure, and that still followed, is to burn the stones at such a temperature as nearly to cause vitrification. They are then crushed by stampers and heavy edge stones to a very fine powder, and after removing any coarse fragments by sifting, the powder is packed in casks and conveyed to its destination. Medina cement is of the same nature as the above, only that the septaria employed are those of Hampshire. Mulgrave or ATKINSON's cement is prepared in a similar way from the lias and other species of rock. Portland cement, which has gained great repute, and is decidedly superior to the others in point of tenacity and durability, is made of the deposit found in the bed of some rivers which have their course over clay and chalk formations, mixed with a certain quantity of carbonate of lime. The mixing is performed very intimately under water; then it is dried and burned in proper kilns, after which it is ground like the other varieties described, sifted, and packed for sale. Cements of various degrees of setting qualities may be formed by calcining clays and limestones in the same way as the foregoing, but much of their power is dependent upon the nature of the clay, and the degree of heat at which this operation is performed. They are, however, for the most part, inferior to those already mentioned, as well in the property of setting under water, as in the tenacity with which they bind bodies together. In these qualities, Portland cement greatly excels. The experiments which were made at the Great Exhibition of 1851, and detailed in the Illustrated Catalogue, testify this fact in a most remarkable manner.

Concrete and *béton* belong to the foregoing class of mortars, and are much used in underground works, and in the foundations of large edifices. They also serve as a backing for walls of great thickness. They are prepared by mixing coarse gravel and fragments of stone with lime, which may or may not have been previously worked up into a mortar.

For water-works, where it is necessary that the compound should set rapidly, a mixture of hydraulic lime, puzzolana, and sand, may be used in the annexed proportion, recommended by TREUSSART:—

30 parts of strong hydraulic lime measured in bulk before being slaked,
30 do. of trass,
20 do. of gravel,
30 do. of sand, and
40 do. of hard limestone broken.

These materials diminished one-fifth after being worked up. The stones and gravel were added after the sand and lime had been mixed up into a mortar. This cement should be used immediately after it is made. When the puzzolana is used, the proportions taken are:—

32 parts of strong hydraulic lime measured before slaking,
45 do. of puzzolana,
22 do. of sand,
60 do. of broken stone and gravel.

This concrete is exposed for twelve hours before it is used.—*Tomlinson.*

For river and sea works, a concrete similar to the above, and answering the required purpose very well, is manufactured by mixing a mortar made of three parts of quartz sand, and one of unslaked hydraulic lime, with an equal weight of gravel or broken stones. No water should be added to the mixture during the time the mortar is being incorporated with the stones and gravel.

If the latter have a smooth surface, they are not so well adapted for the preparation of concretes of this description, as when they are angular and pointed. Granite clippings and other fragments are very eligible for this kind of mortar. Much difference exists between the behavior of concrete and that of béton in water, for the former does not set, and therefore is acted upon by the water, if not protected, whilst the latter is eminently hydraulic.

The other kinds of cement mentioned, such as **KEENE'S**, **MARTIN'S**, Parian, *et cetera*, have gypsum, or plaster of Paris, instead of a hydraulic lime, for their basis. The method of preparation is almost the same in all.

Gypsum differs from those substances hitherto considered, as well in its chemical constitution, as in its behavior as a cement. The several mortars and cements already described, owe their property to the formation of a silicate during the setting, but in the case of gypsum, or plaster of Paris, no such combination takes place; indeed, its hardening properties are rather diminished than enhanced by admixtures of caustic lime or silica.

The induration of gypsum is, however, to be attributed to a union of another kind, namely, of water. Gypsum, or sulphate of lime, when exposed to the air for a length of time, will not set when mixed with water in the usual way, because the necessary amount of constitutional water for the formation of the crystallized salt had been absorbed from the atmosphere. If this substance were, however, exposed to a high temperature, sufficient to expel all the moisture with which it united, and the dry powder blended with water, it would readily harden. The gypsum, in this case, unites with about a fourth of its weight of water, or two equivalents, by which it is rendered crystalline; but besides this amount, it is capable of enveloping or solidifying a much larger quantity. By reason of this behavior, gypsum forms a solid mass with as much as its own weight of water. With such an amount, however, it never acquires much tenacity, but, upon the evaporation of the excess, the portion of the salt which was dissolved assumes the crystalline form, and binds the solid particles more firmly together. This property of gypsum makes it very valuable for many architectural and artistic purposes, but only those connected with cements will here be alluded to. Sulphate of lime when set by water never acquires the tenacity of stone; it always remains soft, so that it may be easily scratched by the nail. This softness was a great impediment to the execution of several works in plaster, and for a long time a remedy was sought, with only partial success. Various suggestions and prescriptions were offered, most of which were unavailing. **GAY-LUSSAC** first observed that the hardest natural gypsum also yields the firmest product after setting in the usual manner. The proposition of hardening gypsum by means of a solution of alum was first made by **PAUWARE**, and carried out with modifications by several persons, and this has proved the best, or one among the best and readiest means by which tenacity may be communicated. Other salts in solution are capable of effecting the same change, some by a double decomposition being induced, whilst with others the theory of the induration by [illegible] means is not so easily demonstrated. The hardening [illegible] alum may be accounted for by supposing that the sulp[illegible] lime is capable of combining with another salt forming [illegible]ary compound, in the same way as sulphate of magnesia unites with other sulphates. However, it is of this behavior of the gypsum with solutions of salts, that advantage has been taken, and patents secured for manufacturing the cements noted above. **KEENE'S** cement is made by mixing the powdered gypsum with a solution of alum, and then baking the compound at a temperature approaching dull redness, so as to dissipate the whole of the combined water. The mixture is again powdered by stampers, or under edge stones, and when used, the powder is slaked by a solution of alum in twelve or thirteen parts of water. Common water might here be employed, but that hardness which is given by the alum liquor could not be attained. **MARTIN'S** composition is made in the same way as the one just described, only that carbonate of soda, or carbonate of potassa, is employed, as well as the alum, and the burning takes place at a higher temperature. Parian cement is prepared by using a lie of borax instead of the forementioned. These varieties are very useful for floorings, skirtings, *et cetera*, and especially where damp and vermin have to be guarded against. These materials, like stucco, may be employed in cementing walls, and their surface can be embellished with various artistic delineations similar to fresco-painting.

Stucco is a compound of powdered gypsum and a solution of glue or strong gelatin, which is employed to coat walls, and also for ornamenting ceilings, and other works of art. It is capable of receiving a high polish, and also of taking designs in color. When employed on walls, the coarser kind is first laid on, and an outer coating of a finer preparation of gypsum and glue, or isinglass, afterwards deposited upon it, and when dry, polished with pumice, tripoli, and linen rubbers. The color is incorporated with the outer coatings of the stucco, by mixing the metallic pigments with it, and then applying it to the wall, after which a very thin coating of gypsum and isinglass, or sometimes of oil, is given; and when the whole has partially dried, the tint is brought out by polishing, as before stated. Generally, the final gloss is given with oil.

MOSAICS.—The process of forming patterns and devices by the cementation of several pieces of colored and other substance, is one exhibiting great art and skill. The ancient Romans excelled in this, as is evidenced by the fragments of pavements and other remains which have been discovered in the various countries they subdued. Rome and Florence still continue pre-eminent in this kind of work; but instead of it being, as of old, exclusively used to decorate walls and floors of buildings, it is now employed by artists for copying the most delicate paintings, the material for this purpose being a kind of very fusible enamel, tinged by metallic oxides. This constitutes the surface of the picture, being supported on a ground of very hard cement. It is said that no less than one million seven hundred thousand pieces of this composition entered into the construction of a portrait of one of the Popes, exhibited at the Great Exhibition of 1851.

The following processes for preparing mortars and hydraulic cements which are used by the Turks, may be interesting:—

Ordinary mortar is prepared by mixing two parts of powdered lime, and one of river sand, with the necessary quantity of fresh water.

Hydraulic mortar. Bricks are saturated till their powder appears of the fineness of common river sand; one part of this is afterwards mixed with two parts of fine lime, and the necessary quantity of fresh water. When using this mortar, it is laid between the bricks, or courses of bricks, in layers as thick as the latter. To render it very binding, the bricks are allowed to remain in water till they become saturated. When the cement is used for the internal dressing of arches, aqueducts, large cisterns, or reservoirs, baths, *et cetera*, it is made in the following manner:—

Two hundred and fifty pounds of milk of lime, and two hundred and twenty pounds of extremely fine plucked tow, are to be mixed together very intimately and regularly. The whole is allowed to stand for eight days, that the lime and tow may form a thorough combination. Before being used, it is well stirred up. It is laid on in the usual way, by means of a small trowel, and afterwards subjected to the dressing, which consists in a prolonged rubbing with the trowel, till the surface is smooth and even. To render the cement unaffected by water and more durable, it is covered with a layer of the following composition:—

250 pounds of fresh burned lime slaked,
62 do. of linseed oil, and about
2 ounces of rough cotton.

The lime is mixed with the oil and cotton in successive portions, till the mass has the consistency of dough. It is then moulded into square blocks and preserved for use. Before being applied, it is stirred up with linseed oil to bring it to the thickness of a stiff paste.

CHEESE.—*Fromage*, French; *Käse*, German; *Caseus*, Latin.—The principles of the manufacture of this so well-known, but, at the same time, highly important product of the dairy, have, unfortunately, not been attentively studied, so that the cheese of the present day is prepared almost precisely in the same manner as it was centuries back.

Cheese may be produced in nearly every locality, yet there is a marked preponderance of this branch of industry in some districts over others. This is not merely a matter of chance, but is dependent upon the kind of husbandry dictated by circumstances, and upon the nature of the food supplied to the cows. In Cheshire alone, nearly a hundred thousand cows are kept solely to produce cheese, so that the whole county may be viewed as a factory, the animals representing the principal machinery for the transformation of fodder into human aliment.

PREPARATION.—It has already been stated under the article BUTTER—see page 395—that milk inspissates on the addition of an acid; and the lactic acid produced from sugar, particularly, possesses the property of rendering insoluble, or coagulating, the casein of milk. This change is practically the commencement of the manufacture of cheese, the numberless modifications of which process may be included under the two following heads:—

Firstly, The milk is either permitted to curdle *per se*, by simple standing, from the spontaneous generation of lactic acid, or—

Secondly, External agencies are used to insure a like result, the chief of these being *runnet*, which is principally prepared from the membrane of the stomach of the calf, though it may be made from that of the lamb, kid, or pig. Indeed, in some districts where the calves are reared, the pig's stomach is exclusively employed, and many believe that it makes the stronger *earning*.

All the different methods of preparing runnet have in view the same object,—that of preventing its putrefaction; this is effected either by salting, smoking, or by a combination of these with the use of spices.

When runnet is salted in the dry state, it soon produces a brine, which will coagulate milk, and is employed for that end. Though it is most common to use only the skin of the stomach, yet in many districts the whole is employed, just as it existed at the death of the animal. In the latter case, the cheese is less easily preserved, the oleaginous matter in the concreted contents of the stomach having a powerful inclination to become rancid.

Many views have been held with regard to the action of runnet in making cheese. Its coagulating properties have long been attributed to the gastric juice derived from the stomach of the animal, and it is not at all improbable that the custom of using the skin, *et cetera*, and also that of throwing the materials away after having been once employed, are owing to this opinion. The facts, however, that in many localities the interior surfaces of the skins are thoroughly washed; that in others they are steeped, even for months, in brine, and are then well drained and desiccated; and also, that after having been once prepared and used for curdling milk, they may be again employed,—prove to a certainty that the efficacy of runnet is not owing to anything originally derived from the stomach, but is dependent upon something emanating from the skin itself.

The change undergone by the flexible skin, during the protracted drying and decay of the salted membranous receptacle, is such as to produce matter *soluble in water*, which possesses the property of converting the sugar of milk into lactic acid.

Various substances have been recommended as substitutes for runnet, such as pure curd, agreeable old cheese, extract of malt, and many others.

The use of curd, prepared in the following manner, has been particularly recommended:—Heat a quantity of milk which has stood five or six hours, let it cool, and separate the cream completely. Add now to the milk a little vinegar, and apply heat gently; coalescence will ensue, and the casein will separate. Pour off the whey, wash, and knead the curd well with repeated portions of water. When pressed and dried, it will be sufficiently pure for all ordinary purposes.

Could the manufacture of runnet be rescued out of the empirical hands of the dairymaid, and a ready coagulation of the milk effected by the use of a simple, abundant, and easily prepared substance, a considerable step would be made towards the perfection of this art.

The utensils required in cheese-making are, a tub in which to earn the milk; a curd cutter; a curd breaker; a drainer to lay across the tub while the whey is straining from the curd; vats for forming the cheese; a cheese press; and a boiler for heating milk, water, *et cetera.*

The curd cutter is represented in Fig. 301, and consists of an oval hoop, A B, generally made of iron, nine inches long, six wide, and about one and a half deep; having a slip of iron, of the same depth, firmly attached to each extremity of its longest diameter. The stems of round iron-rod rising from each side of the hoop unite at C, and, at about eighteen inches from the hoop, terminate in a wooden handle, D. The curd is cut in the tub by the repeated raising and pressing down of the instrument.

Fig. 301.

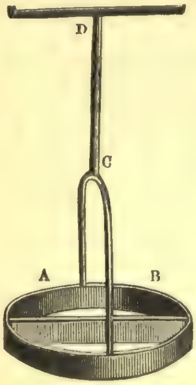
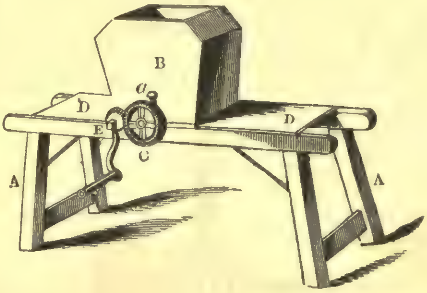


Fig. 302 is a representation of the curd breaker, where A A is a strong timber frame, consisting of two bars, connected with boards, D D, and supported on feet, the position of which is maintained by cross bars and iron stays. At the bottom of the hopper, B, is a cylinder of wood, through which an iron axle passes; on the nearest end of this is a pinion, C, having forty-six cogs, acted upon by a smaller one, E, of twenty-four, bearing the winch-handle by which motion is communicated.

Fig. 302.



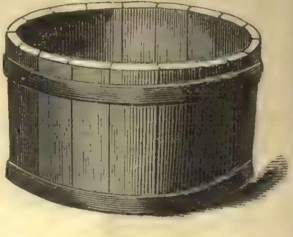
The inside cylinder is furnished with three rows of cutting teeth, placed in diagonal lines, of the form of half a lancet cut through longitudinally, one inch long and five-eighths broad, each rank consisting of thirty-two. The nearest end of the bottom of the hopper is provided with a series of similar cutters, also thirty-two in number, fixed so as to permit those on the cylinder to pass between them when the latter is in motion.

On using this apparatus, the curd, in slices, is placed in small tubs on the boards, D D; and on a portion being introduced into the hopper, the winch-handle is turned, and the curd is cut by the teeth into pieces not exceeding a quarter of an inch in size, which descend into a tub placed beneath for the purpose. One person may both communicate motion to, and feed the machine, but the process is much expedited by having a second to perform the latter.

The whole may be taken to pieces to be cleaned, by unscrewing the pin, *a*, when the axle may be drawn from the cylinder with the large wheel, C, the roller taken out, and the hopper removed from its position by turning thumb-catches, which connect it below with the framing, A A.

Fig. 303 shows the *chessart*, or common cheese-vat, the form of which is varied according to that required for the cheese. It is generally constructed of elm staves, as being least liable to burst on the application of pressure, and is well hooped with iron; the bottom should be made very strong, and pierced with holes, to allow the expressed whey to flow off; a wooden cover, which fits it exactly, is strengthened by being cross-doubled. The whole should be made as smooth as possible in the interior. In Cheshire the vats are made of tin, perforated on the bottom and sides.

Fig. 303.



The varieties of the cheese-press are very numerous; the common kinds may, however, be arranged in two divisions—the old stone, and the combined lever press; the many classes of the latter passing from the single lever, through its various combinations, to the more elaborate one of the rack and levers.

It is an essential characteristic of the last mentioned, that the load, in whatever way produced, shall, *per se*, have the power to follow the sinking of the cheese, occasioned by the exudation of the whey, and also by the consolidation of the caseous particles.

The common stone press is represented in Fig. 304: it consists of a strong frame of wood, of which A is the sill; two uprights, B B, are mortised or dovetailed into it, and these are held together at the top by the head, C. A cubical mass of stone, D, is squared, so as to slide freely between the posts; and into its upper surface is inserted a stem of rod-iron, one inch in circumference, screwed at its higher end, passed through the centre of the head-piece, and secured by the nut, E, which serves for the raising or lowering of the block. In each end of the stone a groove is cut, corresponding to a rib of wood nailed to the middle of the posts, in such a manner as to allow of the weight rising and falling freely, while its inclination to either side is prevented. When put into operation, the block is elevated by means of the screw, until the vat and its contents can be placed upon the sill; the nut, E, is then reversed till the block rests lightly on the cover, and its descent is continued from time to time as the curd consolidates, until the entire weight rests upon the mould.

Instead of the solid mass of stone, which, when fully in action, will always produce the same amount of compression, it is preferable to have one block—the lowest—into which the suspending rod is fixed, and the remainder of the load made up of smaller movable pieces, as shown by the cross lines in the figure, by which means the pressure can be regulated according to the size or state of the cheese. Blocks of cast-iron, which are more convenient and less liable to fracture, are sometimes used in the system just noticed.

Fig. 304.

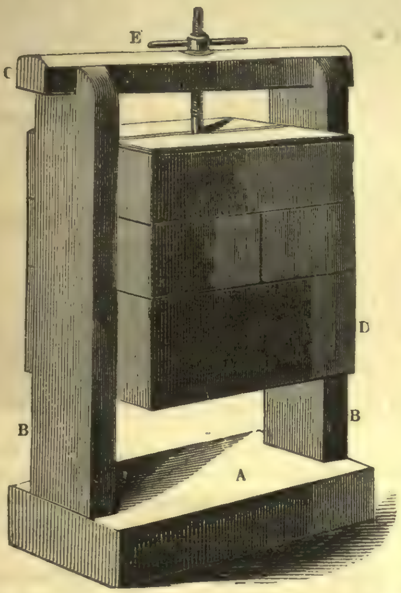


Fig. 305 is a perspective view of the combined lever iron press.

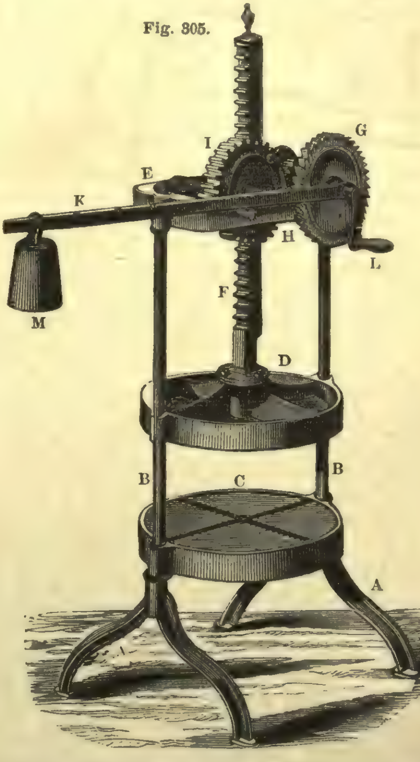
Two cast-iron feet, A A, on which the apparatus is supported, are provided with sockets at the crown to receive the wrought-iron pillars, B B. The plate, C, eighteen inches in diameter, on which the cheese-vat stands when the machine is in operation, is secured to the feet by two perforated ears, through which the lower parts of B B pass. It has channels, represented in the figure by cross lines, to allow the expressed whey to flow away. The movable sill, D, of the same size as the vat-plate, C, and fitted with corresponding ears to slide on the pillars, has the rack bar, F, fixed in its centre. A frame, E, adapted to sustain the gearing of the whole, is attached to B B.

The movement of the rack, F, and the sill, D, is effected thus:—The ratchet wheel, G, turns upon an axle having its bearings in the top frame, and on the same centre is fixed a pinion of eight teeth, only partially seen in the engraving, which works in the wheel, I, of twenty-four cogs; upon the axis of I is another pinion, having also eight teeth, which acts upon the rack. The lever, K, is forked at the extremity nearest the small winch-handle, L, and the terminations of the furcation are received upon the axle of G. A pin near H is adapted to a small hole in the frame, by the insertion of which the descent of the lever may be prevented.

In pressing, the vat is placed upon C, and the lever being upheld by the pin at H, the winch-handle is turned to the left, lowering the rack and sill, till the latter presses upon the cover of the vat. The lever is now raised, and the pall allowed to take into the ratchet, which will cause the latter to turn, and produce the descent of the rack. This is repeated, if requisite, till a considerable pressure is produced; and if it is wished to go on, the lever is elevated considerably above the horizontal line, and left to follow the consolidation of the cheese. If, however, this is not necessary, the pin, H, is inserted, upon which the lever remains. The amount of pressure is also regulated by the disposal of the weight, M, in the various notches of the lever.

The following is the ordinary method of making skimmed-milk cheese, as recited by Mr. Henry Stephens:—On a farm of mixed husbandry, as much skimmed milk cannot be procured every day as will make a cheese of ordinary size, but one may be fabricated each alternate day. To prevent the souring of the milk, therefore, it is necessary to scald it—that is, to put it into the boiler, or furnace pot, to heat it sufficiently, and then allow it to cool. The fire should be very gentle, and the milk should be carefully stirred, and neither permitted to burn nor boil. After being thus heated in the morning, it is poured into a tub, to await the earning of the following day. The skimmed milk of next morning is poured into the same vessel, with the exception of about one-third, which is warmed for the purpose of raising the temperature of the whole to 110° or 112° Fahr. No very exact heat, however, is specific, provided the milk is not allowed to burn at the bottom of the pot, or boil. If the latter occurred, the milk would almost instantly coagulate; and were cheese made from the curd produced, it would be hard and flinty. The runnet is previously prepared by immersing a calf's stomach, which had before been cleansed, salted, *et cetera*, in three imperial pints of very strong

Fig. 305.



brine, contained in a closely covered jar, for three or four days; the resulting liquid is bottled for use, and half a teacupful will curdle milk sufficient to make fifteen pounds of cheese. On the milk in the tub being stirred, the runnet so prepared is added to it, and it is permitted to stand till fully coagulated, which it will be in half an hour, with a cloth thrown over it, to retain the caloric. The curd is then cut with a knife, on which it lets out a portion of its whey, which is removed, as far as practicable, by pressing a plate upon an open linen cloth spread upon it. When comparatively dry, it is chopped with the cutter—Fig. 301—and the whey again expressed. The mass is next lifted out of the tub, and wrapped in the curd cloth, which is placed upon a drainer laid across it, and the whey is expelled, as far as possible, by manual pressure. This is a very laborious operation, and, in large dairies, the mass of curd is sometimes placed in a cheese-vat, and subjected to pressure under large weights, or in the press; afterwards, however, the coagulism becomes very firm, and, to render the breaking of it into fragments more easy, it is cut with a knife into thin slices, which are then reduced to a coarse powder by the curd-breaker—Fig. 302. When made small enough, it is flavored with finely-ground salt to please the taste. In Cheshire, Holland, and other places, the cheeses are floated in a strong aqueous solution of chloride of sodium, which penetrates the pores; but this appears to be a very uncertain mode of giving a desired amount of seasoning.

The curd is next put into a cheese-cloth spread over the vat, and firmly packed into the latter, higher than its edge; when the upper surface has been covered with the remainder of the same cloth, the whole is placed in the press, and subjected to its action, upon which a quantity of whey exudes by the perforations in the bottom of the vat. In a short time—two hours or more—the cheese is turned out, and, after a clean and dry cloth has been put in, is replaced with its upper surface downwards, and again pressed with an accelerated force. Clean cloths should be substituted, the cheese turned in the vat, and the weight be increased each time, as long as any serous matter is expressed; but if the former operations have been properly conducted, the exudation will cease in about twelve hours, after which the pressure is continued until the press is wanted on the second day.

After the cheese is sufficiently consolidated, it is taken out of the vat, and conveyed to the *cheese-room*, where it must not be exposed either to a humid or very dry atmosphere, the former of which would prevent it from hardening, and occasion the acquisition of a bitter flavor; and the latter, drying it too quickly, would cause it to crack. Laid upon the shelves, and surrounded with cool, calm, and moderately dry air, the moisture will gradually evaporate, and a firm skin will be attained. In some districts the cheese is occasionally dipped in hot water for the purpose of hardening the crust, but it seems improbable that any advantage can be derived from such a practice. It should be wiped with a dry cloth, to remove any water which may have appeared, and turned daily.

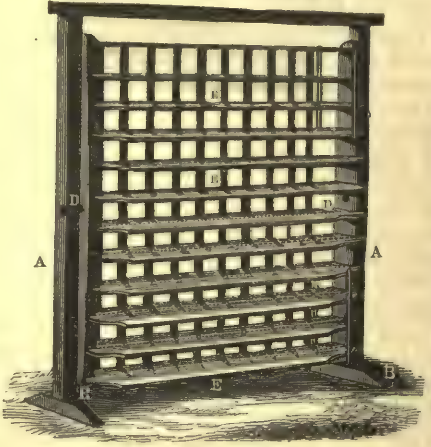
Some cheeses burst, owing to their fermentation, and throw out serous fluid, in consequence of containing whey which ought to have been pressed out. When they alter in shape, there is good reason to believe that there is an internal organic change; but if they do not crack, they will soon become *ripe*, and be mouldy, and may possess a fine flavor. If fissures occur, facility is afforded to the cheese-fly to enter and deposit its eggs, to prevent which they should be filled up daily with a mixture of butter, salt, and pepper, brought to a proper consistency with oatmeal.

In Cheshire, where the cheeses are made very large, they are enclosed in bands of linen before being removed to the drying-room, and these are kept on until a sufficient degree of firmness has been attained.

The time and labor daily required in turning a quantity of cheese are apparent, even to the most casual observer, and to effect a saving, in both respects, a machine was some time ago invented by Mr. Blurton, of Fieldhall, Uttoxeter, the merits of which appear sufficient to warrant its extensive adoption.

Fig. 306 is a view of the cheese-turner as constructed to stand alone. It has an external frame, A A, standing on cross feet, B B, and held together at the top by a rail, C. If required in the cheese-room for constant use, the posts, A A, may be secured to the floor below, and to the joisting above. The second part of the contrivance is a movable frame or rack, formed by the two interior bars, D D, which are framed into the twelve shelves, E E, each fourteen inches or more broad, according to the size of the cheeses manufactured, and one inch thick. They are tenoned into, and lipped over, D D, and are furnished both on the upper and lower sides, by ribs nailed along the back edge. The cut represents a rack constructed to bear five cheeses in each row, and a corresponding number of laths in pairs is fastened in a vertical position, behind the shelves. The frame thus formed is provided with two strong iron gudgeons or pivots, fixed in D D at mid-height, and received into corresponding holes in the outer or bearing posts, so that the shelf-frame is poised upon the two centres; it has also an iron latch at the top and bottom of one end, by which it may be *tilted* and secured, either end up.

Fig. 306.



The knife-edge laths serve to keep the cheeses out of contact with the body of the shelf, thus permitting air to pass under them, while the pair of vertical bars keep them in their proper position on the support. The distance between the shelves is such as to leave a free space of one inch between the cheese and the board above it, and whatever number of cheeses may be laid in the frame, the simple act of tilting it will place each of them on its opposite side upon the shelf, which, before the turning, was above it.

GRUYERE AND PARMESAN CHEESES.—These differ only in the nature of the milk, and in the degree of heat given to the curd in the several parts of the process. The first is entirely made from new, and the latter from skimmed milk. In the Gruyere, nothing is added to impart flavor; in the Parmesan, saffron gives both color and fragrance. The process in both is exactly similar.

A large caldron, bell-shaped, capable of containing from sixty to one hundred and twenty gallons of milk, is suspended from an iron crane, over a hearth where a wood fire is lighted. The lacteal fluid, having been strained, is put into this vessel and heated to 98° Fahr. It is then withdrawn from the influence of the fire, and some runnet is intimately mixed with the warm milk. A cloth is then laid over the caldron, and in half an hour, more or less, the coagulum is formed. If it be longer than an hour coalescing, the milk has been too cool or the runnet not sufficiently strong. When the curd is properly set, it is cut horizontally in thin slices by a skimmer. Each broad piece, as it is removed, is poured along the side of the caldron which is nearest to the operator; by this means every portion of the curd rises successively to the surface, and is sliced thin. The whole is then well stirred, and the vessel replaced over the fire; and a long staff, with a knob of hard wood at the end, and which has small cross pieces, or sticks passed through holes in it, at right angles to each other near the end, is now employed to agitate and break the curd, and the heat is raised. When the curd has been well agitated and broken, the temperature is raised to 135°. The caldron is again swung off the fire, and the coagulum stirred slowly for nearly an hour, when it is divided into small pilules, which are elastic and somewhat tough under the finger. Experience alone can teach the exact feel they should have. The whey, of which a portion is occasionally removed, now floats, and the curd is collected by giving a rapid rotatory motion to the menstruum, and placing a cloth at the bottom, when the caseous matter settles upon it; it is now raised by the four corners, and laid on an instrument resembling a ladder, which is placed across the mouth of the vessel. The whey percolates, and the solid matter remaining is set in a shape or hopp, made of a slip of wood four inches and a half wide, the two extremities of which lie over each other, so that, by means of a cord fixed to one end, and passed with a loop over hooks on the outer surface of the circle, the diameter can be lessened or increased. The curd is forced into this with the hands, and the cloth folded over, when, after a round board, strengthened by cross pieces, has been placed on it, the whole is submitted to the action of the press. An hour after this procedure the cheese is examined and turned, the edges which have protruded over the mould are pared off and placed on the centre, and a fresh cloth is substituted. The ring, by unhooking the cord, opens readily, and is now put on again and tightened. In the evening the cheese is rubbed over with finely-powdered salt, and it remains in the press till next morning.

During the ensuing five or six weeks the cheeses are turned and wiped every day, and a small amount of salt sifted on the surfaces. They are in perfection in about six months, and will keep two years. A quantity of fluid is disengaged during the ripening, and occasions the small round cavities so peculiar to these varieties. They should contain a clear saline liquid, which is called *the tears;* when these dry up, the cheese loses its flavor.

STILTON CHEESE is made by adding the cream of the preceding evening's milk to the morning's yield. The cream should be intimately incorporated with the fresh milk; great attention must be paid to the temperature of both, and much of the quality of the cheese depends upon this part of the process. To have this product in perfection, the management of the cheese after it is made is very important, for the greatest difference is often observable between cheeses from contiguous dairies. The runnet should be very pure and sweet. When the milk is coagulated, the whole curd is removed, drained in a sieve, and carefully pressed. It is then put into a shape in the form of a cylinder, eight or nine inches across, the axis of which is longer than the diameter of the base. When it is sufficiently firm, a cloth or tape is wound round it to prevent its breaking, and it is placed on a shelf.

It is occasionally powdered with flour, and immersed in hot water, which indurates the outer rind, and favors the internal fermentation, which ripens it.

CHEDDAR CHEESE is factured in Somersetshire by the following simple process:—When the milk is brought home, it is instantly strained into a tub and the runnet added, in the proportion of about three tablespoonfuls to a quantity sufficient for a cheese of twenty-eight pounds, after which it remains undisturbed about two hours, when it becomes curdled, and is then broken to pieces. That being done, three parts of the whey are warmed, and afterwards put into the tub for about twenty minutes. The whole whey is then again placed over the fire, made very hot, and returned into the tub, in order to scald the curd for about half an hour longer, after which, part of the whey is again taken out, and the remainder left with the coagulum until it is nearly cold. The whey is then poured off, the curd broken very small, put into the vat, and pressed; it remains there nearly an hour, and is then removed, turned, and set under the press again until the evening, when it is re-turned, and left till the next morning. It is then taken out of the vat, salted, put into it again with a clean dry cloth round it, and it remains in this state till the following evening, when it is once more removed, salted, submitted to the vat without any cloth, and pressed for twelve hours. After this treatment, it is salted once a day for twelve days.

NEUFCHATEL CHEESES, which are imported from France as a delicacy, folded in paper, are made from cream thickened by heat, and pressed in a small mould. They undergo a rapid metamorphosis, first becoming sour and then mellow, in which state they must be eaten.

SWEET-MILK CHEESE.—This is made in the same manner as has been described, but the milk, instead of being skimmed, is operated upon in the state in which it is taken from the cow. One day's yield being insufficient for a cheese, the fresh morning's milking is added to those of the previous day, the oldest part of which will have thrown up a layer of cream; this is mixed—by agitation—through the milk, and the entire gatherings are sufficiently heated. The runnet is applied in the same manner as for ordinary cheese, but in rather larger quantity. Greater difficulty will be found in expelling the whey from the curd, than from that of skimmed milk, and it is this that renders sweet-milk cheeses more liable to ferment, burst, and lose their shape.

CREAM CHEESE.—In preparing this dainty, the cream, in this country, is generally either tied up in a cloth, or put into a shallow cheese-vat, and allowed to drain without any addition; the caseous matter and butter thus remain intimately intermixed, and the product is more or less rich, according to the proportion of butter to the casein in the cream. Such cheese soon acquires rancescence, and becomes disagreeable to the taste; the moist curd, after continued exposure to the air, not only decomposes and becomes unpleasant of itself, but induces a metamorphosis in the butter, and imparts to it an offensive flavor.

CHEESE FROM GOAT'S MILK, ET CETERA.—Cheese, much esteemed in France, is made at Mont d'Or from the milk of goats. The principal difference appears to be in the runnet employed, which is of three kinds, and consists either of clear whey, in which a certain proportion of salt has been dissolved, and a number of kids' stomachs boiled; of white wine, to which the membranes, as also salt, pepper, and aromatic leaves, have been added; or of vinegar. The cheese, however, according to M. GROGNIER, owes its good quality, and consequent reputation, as well to the regimen and food of the goats, as to the manner in which the milk is treated.

Cheese is also obtained from the milk of sheep. The quality of Roquefort cheeses, which are of this kind, and are very excellent, depends, to a great extent, upon the places in which they are stored after pressing, and during maturation. These are cellars, communicating with grottoes and caverns, which are kept constantly cool—at about 41° or 42° Fahr.—by currents of air from the clefts in the mountains.

The production of cheese is not confined, as is generally supposed, to the animal kingdom. An excellent article is made in Thuringia and Saxony from potatoes, a quantity of which is boiled, and, after cooling, peeled and reduced to a pulp. To each five pounds of this, is added one pound of sour milk, when the whole is worked up, and allowed to rest for three or four days. It is then again kneaded, and the cheeses are laid in little baskets, to allow superfluous moisture to escape; afterwards they are placed in layers in large vessels, where they must remain fifteen days. The older they are, the more their quality improves; they do not engender worms, and will keep fresh for years, if placed in a dry situation, in well-covered vessels.

Cheese has been made from buttermilk; and the Chinese have, for an indefinitely long period, produced it from peas and beans.

COLORING OF CHEESE.—Mr. STEPHENS has very justly disapproved the use of annotta for coloring cheese, as a worse than useless piece of trouble, since not only is there no advantage derived from it, but cases of poisoning have been traced to the employment of the cheaper kinds, which are often contaminated with *minium* or *red lead*—$Pb_3\ O_4$. If annotta imparts no peculiar flavor—which has long been acknowledged—of what utility is it? As to improving the appearance, it cannot be denied that the Stilton and Dunlop cheeses look as well on the table as the Gloucester and Cheshire products. Marigold flowers, saffron, and carrots, have been employed for a similar purpose.

COMPOSITION.—The main solid constituent of cheese is casein, a principle similar to the fibrin of wheat, the legumin of the pea and bean, and the albumen of the egg or of vegetals. Hence the opinion entertained by MULDER and others, that the caseous matter contained in the milk of animals is derived directly, and without any remarkable metamorphosis, from the food on which they live, has been generally adopted.

Casein may be procured almost in a state of purity, by adding a few drops of acetic acid to *well-skimmed* milk, having a temperature of about 150° Fahr.; the coagulum thus obtained is thrown upon a linen strainer; repeatedly affused with water; pressed dry; digested first in boiling alcohol, afterwards in ether, and then carefully exsiccated. This residue, reduced to an impalpable powder, and re-digested in ether, till perfectly free from all traces of fatty matter, and lastly, dried at 240° Fahr., yields a white, opaque, insipid, inodorous, hard substance, insoluble in water, which is nearly pure casein.

It has a strong tendency to unite with both acids and bases; the precipitates formed by adding the former to milk are not permanent compounds of casein with the respective acids, as nearly the whole of the latter may be washed away by water.

Casein precipitated by acetic acid, kept under water in a covered vessel, at first sours, then eliminates ammonia, and acquires the odor of stale cheese.

It is distinguished from albumen by a weak solution of it not curdling when heated, and by being precipitated from this by acetic acid. Coagulability by runnet is also one of its distinctive characteristics. It has been repeatedly analysed by several chemists, who found that it consisted of carbon, hydrogen, oxygen, nitrogen, a little more than a quarter of a per cent. of sulphur, and intimately combined with a certain amount of phosphate of lime.

Cheese also contains water, in the proportion of about thirty-five to forty-four per cent., as also some fatty matter, which is least in the poorer kinds, and from two to six per cent. of inorganic salts.

The following analyses of cheese were performed in the laboratory of Professor JOHNSTON :—

Kind of cheese.	Centesimally represented.				Remarks.
	Water.	Casein.	Fat.	Ash.	
Skim-milk cheese; made June 1845, analysed June 1846,	43·80	45·04	5·98	5·18	Made in Lanarkshire on a poor, cold, wet, upland moor farm.
Double Gloucester cheese; made June 1845, analysed July 1846,	35·82	37·96	21·97	4·25	
North Wilts cheese; made June 1845, analysed June 1846,	35·58	25·02	30·11	6·29	
North Wilts cheese; made September 1845, analysed September 1846,	36·34	31·12	28·09	4·45	From a rich loam, with gravel subsoil.
Dunlop cheese; made at Wellwood 1845, analysed 1846,	38·46	25·87	31·86	3·81	
North Wilts cheese; made July 1846, analysed September 1846,	40·58	28·25	27·44	3·73	From a loam, with running sandy-clay subsoil.
North Wilts cheese; made May 1846, analysed September 1846,	44·80	28·17	23·04	3·99	From strong clay soil, inclined to be very grassy.
Cheddar cheese; made 1845, analysed Feb. 1847,	36·24	28·98	30·40	4·38	From a rich deep soil in the marsh near Cheddar.

The inorganic constituents are only due in part to the milk. The earthy phosphates attach themselves to the curd in the making, while the soluble salts remain principally in the whey. The cheese being cured with chloride of sodium, the quantity added varying with circumstances, the additional constituents of the ash are lime, a little magnesia, soda, potassa, traces of iron, chlorine, phosphoric and sulphuric acids.

	Dunlop cheese.	Skim-milk cheese.
Per centage of phosphates in the ash, ...	53·38 ..	52·64
Per centage of phosphates in the cheese,..	2·03 ..	2·58
Per centage of salt in the ash,...........	32·37 ..	42·13
Per centage of salt in the cheese,........	1·23 ..	2·06

PROPERTIES.—Fresh cheese is very sparingly dissolved by water, but after having been left to itself for two or three years, it becomes—especially if all the fat be previously removed—almost completely soluble, forming a solution which, like milk, is coagulated by the addition of acids.

The cheese which is insoluble when fresh, returns, during the ripening, to a state similar to that in which it existed in the milk. In the English, Dutch, and Swiss cheeses which are nearly inodorous, and in the superior French kinds, the casein is present in its unaltered condition. The odor and flavor are owing to the decomposition of the butter; the non-volatile acids—margaric and oleic—and butyric, valerianic, caproic, caprylic, and capric acids, which are volatile, are liberated in consequence of the decomposition of glycerin, and the variations in its pungency depend upon the proportion of the latter acids present, which, with their respective formulæ, are annexed :—

Butyric acid, ...	$C_8\ H_8\ O_4$
Valerianic acid, ...	$C_{10}\ H_{10}\ O_4$
Caproic acid, ...	$C_{12}\ H_{12}\ O_4$
Caprylic acid, ...	$C_{16}\ H_{16}\ O_4$
Capric acid, ...	$C_{20}\ H_{20}\ O_4$

In the Limbourg cheese, the valerianic acid occurs in the largest quantity. BALARD first discovered it in the cheese of Roquefort.

All the above acids, it will be observed, are homologous substances.

The bad smell of inferior kinds of cheese is caused by certain fetid products containing sulphur, and which are formed by the putrefaction or decomposition of the casein. The alteration which the butter undergoes in becoming rancid, or which occurs in the milk-sugar still present, being transmitted to the casein, effects a change in its composition, and deteriorates its nutritive qualities.

Cheese is eaten for two very different purposes, either as a part of the regular food, for the general sustenance of the body, or as a kind of condiment, taken in small quantity along with, or after, the usual fare, as is common at dinner-tables. It is chiefly the older and stronger-tasted varieties that are used in the last sense, and they are generally very wholesome and digestible. The action which experience seems to have proved cheese, eaten after dinner, to possess, in aiding the digestion of what had previously been partaken of, is both curious and interesting, and has had some light thrown upon it by recent chemical research.

When the curd of milk, says JOHNSTON, is exposed to the air in a humid state for a few days at a moderate temperature, it begins gradually to decay, to emit a disagreeable odor, and to ferment. It now possesses the property, under certain circumstances, of inducing an eremacausis in other moist substances with which it is either mixed or brought into contact, acting similarly to sour leaven when incorporated with dough.

In the same way, old cheese, when introduced into the stomach, causes the commencement of metamorphoses among the particles of food previously consumed, and thus facilitates the dissolution which naturally precedes maturation. It is only some kinds of cheese, however, which will effect this purpose, those being considered preferable in which some species of mould has established itself: hence, the mere eating of a morsel after dinner does not necessarily promote digestion; if too new, or of improper quality, it will only add to the load of food already on the stomach, and will have to await its turn for concoction by the ordinary process.

Dr. WHITLING is said to have found hydrocyanic—prussic—acid, as a spontaneous product of the decay of cheese. TAYLOR has, however, shown that this is not the case. He examined many samples in various stages of decomposition, from which he obtained only an acrid oil and sesquicarbonate of ammonia. Large quantities of unsound cheese are sold to the poor in London and elsewhere, but effects resembling those which hydrocyanic acid would occasion are unknown.

ADULTERATION.—As has before been noticed, lead has been found in cheese, but its presence has been traced, by different chemists, to the employment of sophisticated annotta, so that any cheese which might have been colored with such would have been decidedly poisonous. This adulterant may be detected by incinerating an ounce or two of the suspected article, and then submitting the ash on charcoal to the reduction flame of the blowpipe, by which a ductile button of the metal will be obtained; the support, if very strong indications are not afforded, should be inspected, after the operation, with a powerful lens, as globules may result of such a size as to elude the unassisted powers of vision.

To confirm the blowpipe analysis, a portion of the cheese-ash may be dissolved in weak nitric acid and filtered; the filtrate being, subsequently, submitted to a stream of sulphide of hydrogen, will yield a black or dark-brown coloration or precipitate, depending upon the quantity of lead present.

Cheese is also perverted with potatoes boiled or mashed: there is nothing, however, in these esculents harmful to the animal economy; their addition is simply a fraud, and is easily detected by boiling a portion of the suspected cheese with water, and, when the decoction is cold, adding a small quantity of iodized spirit or water; should starch—which exists abundantly in potatoes—be present, a blue tinge will immediately appear.

STATISTICS.—The imports of cheese into Great Britain, during the last three years, were as follow:—

Years ending 5th Jan.	Tons.	Official value.
1853	14,275	£287,903
1854	20,164	397,411
1855	24,195	478,815

CHLOROFORM.—*Chloroforme*, French; *Dreifach Chlorformyl*, German.—It may be safely affirmed, that no well-ascertained fact, or series of facts, can possibly exist which are not worthy of earnest study. It is no answer to say that there are many facts of no tangible importance; the fallacy of this statement has been often refuted by experience. When SOUBEIRAN first described a peculiar volatile fragrant substance, produced by the action of oxychloride of calcium upon alcohol, the fact of its production was recorded, and stood for many years in the manuals of chemistry as a mere scientific curiosity; yet, when the time came, this insignificant liquid, under other hands, started up into the highest practical value as *chloroform*. Now, had *all* the properties of this body been at first *carefully studied*, mankind would not have had to wait so long for the boon which it is found to confer, in relieving the suffering and afflicted. The sole and exclusive object of SOUBEIRAN, DUMAS, and others, was the investigation of a point in philosophical chemistry. They labored for the pure love of knowledge and its extension. They had no idea that the liquid to which they called the attention of their chemical brethren, could or would be turned to any *practical* purpose, or that it possessed any physiological or therapeutic effects upon the animal economy. This circumstance is stated as a striking proof, that the *cui bono* argument against chemical researches, on the ground that there may not appear at first any practical benefit to be derived from them, has been amply refuted in this, as it has been in many other instances.

Chloroform is obtained in a variety of ways, and this article might be extended to an indefinite length, if all of them, or even a tithe were introduced. It will be desirable, therefore, to give only the best process. This consists in distilling a mixture of one pound of oxychloride of calcium, three of water, and three of pure alcohol, in a capacious retort. About three ounces of chloroform pass over, which are to be well affused with water and rectified, after being agitated for a short time with concentrated sulphuric acid, which removes traces of water, and destroys certain oils which are usually present in small quantity. The rectified product should not tinge oil of vitriol when shaken with it, unless in a very trifling degree. If it colors the acid strongly, or if, when evaporated on the palm of the hand, it leaves an unpleasant odor, it is not fit for use, and must be again well aspersed with water and re-distilled.

When perfectly pure and carefully rectified, chloroform is quite limpid, very mobile, almost like hydrated ether; it refracts light powerfully, is very volatile, and has a peculiar and rather pleasant odor; it has likewise an agreeable, soft sweet taste, taking no effect on the throat, like so many of the preparations which contain chlorine. Although so volatile, it does not produce any very powerful sensation when put upon the hand; this action is much more marked with ether. It boils at 140° Fahr., and has a specific gravity of 1·494. It is not inflammable, at least with a spirit-lamp, or by the approach of any flaming body; but if thrown upon hot coals, it immediately ignites, diffusing much smoke, and producing a very beautiful green flame. When chloroform contains even *twenty per cent. of alcohol*, it does not burn at a candle on the application of a paper impregnated with it. It requires one quarter of its weight to do so, and then it burns with a green flame; but the combustion even with this quantity does not continue, if the paper be removed from the flame; for this thirty per cent. of alcohol is necessary.

Chloroform, having the above specific gravity at 59° Fahrenheit, has a very remarkable peculiarity, namely, that the addition of one, two, three, four, and five per cent. of alcohol renders it opaline; if the proportion is augmented to ten per cent. it becomes again perfectly limpid, retaining its transparency ever afterwards.

It is very slightly soluble in water, in which it sinks; with alcohol and ether it readily forms transparent solutions, which burn with a yellow and smoky flame. Water, added to the spiritous menstrua, separates the chloroform, which precipitates. Camphor, caoutchouc, wax, amber, copal, and all the common *resins* readily dissolve in it. With black and red sealing-wax, it makes a strong varnish. It does not dissolve sulphur or phosphorus, but iodine and bromine readily, forming deep-red solutions; it coagulates albumen; it floats in concentrated sulphuric acid, which is only darkened by it at a boiling heat, and then it is dissipated in vapor. Nitric acid is tardily decomposed by it in the cold, but when the temperature is elevated, deoxidation occurs rapidly, nitrous acid being abundantly eliminated. It has no bleaching properties; it does not affect iodide of potassium, nor does it dissolve gold, either *per se* or when boiled with concentrated nitric acid, which is rather singular. Nitrate of silver occasions no precipitate with chloroform; a slight turbidity appears, which this compound also produces when dropped into distilled water. It leaves intact chloride of gold, even when boiled with it.

The vapor of chloroform, passed over copper or iron in a state of redness, is decomposed, giving rise to a metallic chloride and a deposition of carbon; no inflammable gas is evolved. It is not acted upon by potassium or sodium; a few bubbles of hydrogen are sometimes evolved, but it may be distilled over the alkali-metal without change. Potassa or soda does not decompose it, except after long ebullition, when it is entirely converted into a chloride and a formiate. When inhaled from a sponge or handkerchief, it very soon produces insensibility—indeed a kind of *coma.* If too sparingly or timidly applied, the effect is often arrested at a stage of excitement similar to that produced by inspiring nitrous oxide; but not being a gas, it may be held so near the mouth on a pledget of linen, and such a quantity administered that the recipient is carried beyond stimulation into a complete lethargy. DUMAS has analysed chloroform, and found it to consist of—

		Centesimally.	
		Theory.	Dumas.
2 Eqs. of carbon,…………	12·0 ..	10·04 ..	10·24
1 Eq. of hydrogen,………	1·0 ..	0·84 ..	0·83
3 Eqs. of chlorine,………	106·5 ..	89·12 ..	88·93
1 Eq. of chloroform,……	119·5	100·00	100·00

Formula: $C_2 H Cl_3 = Fo Cl_3$.

It may be regarded, then, as the terchloride of formyl, that is, formic acid, in which three equivalents of oxygen are replaced by three of chlorine: thus—

Formic acid,………………………… $C_2 H O_3$
Chloroform,………………………… $C_2 H Cl_3$

MANUFACTURE.—An extensive chemical manufacturer has furnished the Editor with the following process for preparing chloroform:—

One hundred and thirty pounds of oxychloride of calcium — bleaching powder — and seven pounds of ordinary lime, with sufficient water to form a paste, are introduced into a capacious alembic of common earthenware. When well stirred together, more water is added, with twenty-five pounds of rectified spirit of wine. Care must be taken that the still is not more than half full; the head is then well luted, and a gentle steam heat applied.

The chloroform which distils over as an oil, is separated from the accompanying liquor by elutriation, and well washed with distilled water. The washings and supernatant fluid, with half of the above quantities of bleaching powder, lime, and spirit, are then introduced into the still, and the several processes repeated.

The whole of the product thus obtained is poured into an ordinary still, with four or five times its weight of distilled water, and a small quantity of lime. On the application of heat, it bubbles through the water, and passes over with aqueous vapor; from this it is removed by means of a separatory funnel, then agitated with a little highly-dried carbonate of potassa, to abstract from it a small portion of water which it retains, and is finally rectified.

This method, when properly conducted, affords a very pure and excellent article.

For the introduction of chloroform as an anæsthetic remedy, mankind is indebted to Dr. SIMPSON of Edinburgh; and although ether, benzol, and many other liquids produce insensibility to pain, this is, of all, the most certain and powerful, as well as the most manageable, which is a very high recommendation. Of course, particular care must be exercised to insure its purity, for the oils which accompany it when first formed are very injurious, and, in administering it, one person should do nothing but watch the pulse and respiration of the patient, and remove the chloroform if necessary. With due care, chloroform is by many considered safe; and ordinary skill and precaution will no doubt prevent its being employed in cases where its use is contra-indicated by disease of the heart, or by marked tendency to apoplexy. Nevertheless, the Editor is of opinion, that it ought to be brought into requisition only in very few instances. Its effect upon unborn generations cannot be anticipated, and he thinks that for accoucheurs and dentists to give chloroform in simple cases, even at the earnest solicitations of patients, is most reprehensible. Doubtless, many accidents, and even deaths occur, not from the effects of the chloroform itself, but from the poisonous action of the deleterious oils, and other adventitious matters contained in that which is sold. Medical men, however, ought to think very seriously before administering to sufferers even the purest preparation. It may be considered as one of the good things introduced by science, but how often are the best of these abused!

ADULTERATION.—It is to be deplored that a substance of so much value as chloroform should, in many instances, be rendered positively dangerous or even fatal, by carelessness in its fabrication, owing to which, impurities, that might be easily avoided in the first instance, or subsequently removed, are suffered to contaminate it, sometimes to such an extent as to render it either inefficacious for good, or positively poisonous when administered.

The foreign ingredients most frequently met with are alcohol, aldehyde, hydrochloric and hypochlorous acids, and some of the compounds of methyl. The latter are exceedingly poisonous in their action; and further, there is no ready means of discovering their presence, or of freeing chloroform from them. Alcohol may be detected by adding one or two crystals of chromic acid to two drachms of the suspected liquid; should it be present, the chromic acid is soon reduced to the state of the green sesquioxide of chromium. The same result is obtained by adding a little bichromate of potassa and sulphuric acid, instead of the chromic acid.

M. BESNOU, who has just published some interesting remarks upon chloroform, writes, that bichromate of potassa certainly affords a very good means of recognising the presence of alcohol; but as it might possibly give rise to controversy between two operators, he gives the details of his own observations, which are as follow: At a density of 1·4945, chloroform, put in contact with bichrome and sulphuric acid, takes a slight greenish-yellow tinge. With five per cent. by weight of alcohol the reaction is clear; a bluish-green zone appears, sufficiently dark to be instantly appreciated by any one with a little experience; but it is very difficult, if not impossible, to discover by this reaction even a good approximation to the proportion of spirit, and that, more especially, from the way in which the operation is conducted. Thus, if one takes a concentrated watery solution of bichromate of potassa, and adds to it a few drops of sulphuric acid, the latter, being very dilute, will decompose the former very tardily; and it is necessary that the chromic acid should be liberated for the decomposition to occur; then the change cannot be produced, or will not, at any rate, appear till the next day.

The above-mentioned chemist operates in the following manner, and finds the reaction to take place instantaneously. He takes about a milligramme of powdered bichromate, or a small crystal, and puts it into a glass tube of four and three-quarters to six inches in length, and rather more than half an inch in diameter; he next adds four or five drops of strong sulphuric acid, stirs with a glass rod, when the ruby color appears; then adds three or four drops of water, to cause the solution of the chromic acid; and lastly, pours in three or four centimetres of chloroform—one to one inch and a half cubic measure—shakes quickly for twenty seconds, and leaves the whole to repose; very soon the rich green of the chloride of chromium appears, if the proportion of alcohol amounts to five per cent., and is deposited in a distinct layer at the bottom, whereas the upper part is barely colored a very pale green.

If the chloroform be pure, the mass is scarcely tinged of a greenish yellow, and there is no separation of any layer. If it has been adulterated with ether, the results are precisely similar.

Dr. LETHEBY thinks that much of the chloroform used in America is contaminated with alcohol; for it has the low specific gravity of 1·45. This also may be one of the reasons for the unsatisfactory accounts which have come from that country of its bad and variable effects.

Aldehyde is recognised by its reducing action on the hydrated oxide of silver, and by its rendering *aqua potassæ* of a brown color when heated with it. This body does not occasion any injurious influence when inhaled with the chloroform, but it is likely to be converted in the system into acetic acid, which is a slight stimulant.

Hydrochloric acid is a very common impurity in chloroform, and often exists in it to a very considerable extent. That containing this acid has often an irritating odor; it reddens litmus paper, and affords, when shaken with a solution of nitrate of silver, a white precipitate.

Hypochlorous acid may be recognised by its odor, as also by its reddening, and then partially bleaching, a piece of litmus paper.

Compounds of Methyl.—It is to be regretted, says NORMANDY, that these dangerous substances cannot very readily be detected. One of the best criterions of their presence is the effect they produce upon the organism. They occasion a peculiar throbbing headache, and a rapid prostration of the vital powers. These symptoms may often be observed when the chloroform is only inhaled for a short time; and there can be no doubt that they are very often the cause of discomfort, so often resulting from the use of certain samples of this anæsthetic.

These impurities may be got rid of in the following way:—Wash the chloroform three or four times with its own bulk of water, decant the latter carefully after each operation, then introduce it into a retort with four or five times its weight of powdered quicklime, and carefully distil on a water-bath. The resulting product will generally be quite pure.

Chloroform may likewise contain water, not added intentionally, for it does not mix readily with it directly, but acquired in the process of distillation. Potassium will show the presence of this body, for when added to any *aqueous* solution it inflames. It is not prudent to crush the potassium to facilitate the reaction or hasten the result of the experiment, for it then frequently happens that a sudden inflammation along with a slight detonation takes place, which projects the liquid out of the glass, and may possibly throw a piece of the metal into the eye of the operator, which would occasion serious, if not dangerous consequences.

All the above means are more or less useful for ascertaining the actual purity of chloroform, *but none of them* indicate the proportion of the sophistication. The presence of alcohol is most to be apprehended, either from negligence in the rectification, or from after addition. M. BESNOU endeavored to find an easy method of determining the quantity, and thinks he has succeeded in discovering an economical method within the reach of everybody. It is based upon the use of the densimeter, and the areometer for acetometry.

He operated upon mixtures in various proportions, and compared their densities. These are appended under the form of a table which will enable the reader at once to follow the differences. It is from 100, as indicating perfect purity, to 75 of chloroform, or from 0 to 25 per cent. of alcohol in the liquid. In this table, *absolutely* pure anhydrous chloroform is not alluded to, but only the commercial product, and such as may be obtained by the ordinary operation of its manufacture; for its density attains a higher figure than 1·4945, as first noted. The compiler of the table has never obtained chloroform having a specific gravity of 1·496, as mentioned by many authors. He believes that, to attain this point, it must be brought to a lower temperature than the mean which he has taken as a starting point:—

Real density.	Corresponding degree of the areometer.	Proportion of alcohol of specific gravity 1·35 mixed with it.	Ponderable quantity of alcohol per cent.
1·4945	47·60	—	0·00
1·4908	47·38	1	0·50
1·4874	47·16	2	1·00
1·4845	46·94	3	1·50
1·4772	46·47	5	2·50
1·4602	45·40	10	5·00
1·4262	43·00	20	10·00
1·4090	41·82	25	12·50

The diminution of the specific gravity by each per cent. of alcohol mixed with it at 40°, is consequently ·0034, whence it results, that chloroform mixed with ten per cent. of alcohol loses thirty-four degrees of the densimeter, and with twenty per cent. sixty-eight degrees; thus the density being determined by the areometer for specific gravity, to estimate the mixture it will only be necessary to divide the known difference by ·0034.

CIDER.—*Cidre*, French; *Aepfelwein*, German.—Cider is the juice of the apple, expressed and submitted to the vinous fermentation.

Its manufacture is of considerable importance, and its qualities have long been known and appreciated. As a summer drink, its reputation is fully established, and it is in great demand, being less subtle and impetuous than wine.

HISTORICAL SKETCH.—The introduction of this beverage is generally attributed to the Normans. As, however, the term *cider* was applicable to all kinds of strong liquors, except wine, as the apple is repeatedly mentioned in Holy Writ, and the beverage produced from it was celebrated by the Greek and Roman writers, it is reasonable to suppose that it was long known to the most ancient nations. Cider is alluded to by TERTULLIAN and St. AUGUSTINE, from which some have supposed it to be of African origin, and that it was brought into Europe by the Carthagenians. It has been thought by others that it was first noticed in England about the time of the Conquest, though, in contradiction to this, it is asserted that the apple was plentiful in Britain centuries before that era. WHITTAKER says that its use was introduced by the Romans. The exact date of its origin in this or in any other country cannot be affirmed, however, with positive certainty.

No nation has so highly appreciated the merits of cider as the English; and PHILLIPS has immortalized its virtues in a classical poem in imitation of the Georgics of VIRGIL, which, says Dr. JOHNSON, needs not shun the presence of the original.

MATERIALS.—The source of cider has been already stated. It will be advantageous, however, to show what kind of apples are best suited for the purpose. Not only has the kind or variety of this fruit a very considerable influence on the liquor produced, but it is very materially affected by the weather, and still more by the soil in which the tree has grown.

The varieties of the apple are almost innumerable, but they may be arranged into three classes; namely, sweet, bitter, and sour or acid apples.

The bitter kinds are best adapted for making good cider; they yield a thicker juice, richer in sugar, clearing better, and keeping longer. The sweet stand next in point of excellence, but the sap is more difficult to clarify.

Other things being equal, the crushed fruits which yield a liquor of the greatest density, will be those which contain the most saccharine matter. The later apples are generally of this description.

In Herefordshire and Devonshire much solicitude is shown regarding the quality of the fruit. In parts of Ireland, says DONOVAN, where as fine cider is made as in any other locality, and where the common English cider would find no favor, owing to its peculiarity of taste, very little attention is paid to the nature of the apple. They conceive that a mixture of every variety that can be procured produces the best beverage; and they always admit a portion of *crabs*, which makes the Irish product more sour than the English; a quality which, when not too predominant, adds to its value among the natives. The Editor is aware that the flavor of the cider is materially affected by the kind of fruit employed; still, with DONOVAN, he believes that the point is not worthy of the importance attached to it by the English growers, and that the quality mainly depends upon the manipulation.

Amongst the many sorts of apple cultivated in the English cider districts, the new Foxwhelp—a seedling from the old—the Wilding, the Cherry Pearmain, the Yellow and Red Norman, seem to be preferred. A long dissertation on the various modes of grafting, planting, *et cetera*, would be altogether out of place here, and the methods practised are so numerous as almost to defy description.

The soil best suited to the growth of apples from which cider of the best quality may be made, is *a deep red, rather tenacious loam.* The same sort of apple grown on gravel, subsoil, or limestone, will yield a juice not equal in specific gravity, and the fermentation of which is said to be more uncontrollable.

Such a loam soil as the above named is most extensively developed in the triangular district embraced between the towns of Hereford, Bromyard, and Ledbury, in Herefordshire; but it is not confined to that locality, as it extends over the other side of the river into Gloucestershire.

The apple consists of ligneous matter as its solid fabric, including other substances, the chief of which are water, malic acid, and sugar.

Appended is a tabulated view of the composition of this fruit, according to the analysis by BERARD:

	Centesimally represented.
Water,	86·28
Sugar,	6·45
Ligneous matter,	3·80
Gum,	3·17
Malic acid,	0·11
Albumen,	0·08
Chlorophyl,	0·08
Lime,	0·03
	100·00

The apple yields, when calcined, 0·27 per cent. of ash, the composition of which, according to Dr. RICHARDSON, is subjoined:—

	Centesimally represented.
Potassa,	35·68
Soda,	26·09
Lime,	4·08
Magnesia,	8·75
Sulphuric acid,	6·09
Silicic acid,	4·32
Phosphoric acid,	12·34
Phosphate of sesquioxide of iron,	2·65
	100·00

The gathering of the fruit is generally performed by shaking the trees, and then pulling what has resisted this treatment and still remains on the boughs. This method blemishes the apples, a disadvantage, however, which it would be difficult to avoid, without incurring a large increase of manual labor and its attendant expense. In Herefordshire and Worcestershire the apple is allowed to hang on the trees till it falls off spontaneously.

PREPARATION.—In cider countries, the greatest part of the beverage is prepared at the time when the fruit is most completely matured,—about a month or six weeks after the apple harvest; it is then also that the amount of sugar has attained its maximum.

The chief machinery requisite for the production of cider are, a mill for grinding the apples; a press for separating the juice; a number of hair-cloths for containing the pulp when ground; a sufficient supply of vessels for the fermentation, racking, and storing; and the implements necessary for removing the pulp from the mill, bottling, *et cetera.*

It cannot certainly be expected that small growers should go to the expense of procuring elaborate machinery: nevertheless, the extreme clumsiness of the present wasteful system would fully warrant considerable cider producers in erecting suitable buildings and apparatus. It is true that some improvements have been made; larger mills are used, and in the press department a tolerably easily worked iron screw has been substituted for an awkward wooden one; but much more still remains to be done, and it is to be hoped that the ingenuity shown in the mechanical departments of other manufactures will soon be applied in the production of this beverage.

Crushing.—The machine used for this purpose in Herefordshire consists of a circular stone in the form of a solid, broad wheel, about three and a half feet in diameter and one foot wide, which is worked by a horse, in a circular trough of stone, the diameter of which is about ten feet, with a depth of eight inches. In this the apples are placed,—great care having first been taken to pick out all that appear rotten,—and the grinding proceeds slowly, a free access of air being allowed to the fruit, till it is reduced to a homogeneous mass, in which the rinds and kernels are scarcely distinguishable from the pulp,

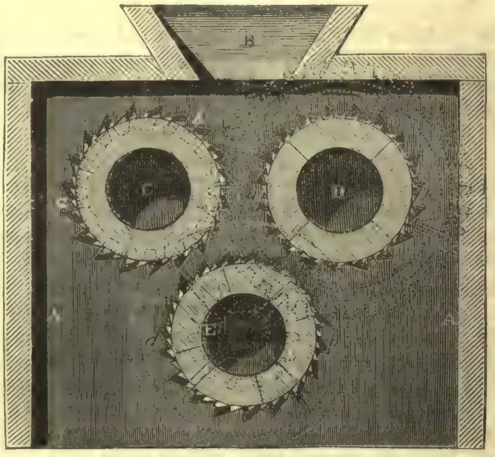
The material of which the crushing mill is constructed should be of the hardest description: granite is generally used. If soft stone were employed, any calcareous substance it might contain would be acted upon by the malic acid of the apples.

In Normandy, the revolver is made of wood, placed vertically as in Herefordshire. The turning cylinder, says DUMAS, should not be of stone, the abrasion of which against the bottom of the trough must result in the crushing of the pips, and their oil, escaping on the application of the subsequent pressure, will impart to the cider a peculiar and very disagreeable taste.

In many places channeled cylinders, capable of moving nearer to or further from each other, are substituted for these turning rollers, which require more manual labor, and are more costly in the first erection. They are fed by a hopper supplied with apples, and are similar in principle, as also to a great extent in construction, with the malt mill shown in Figs. 156, 157.

A mill analogous to this is used in Ireland, but the cylinders, which are made of hard wood, instead of being fluted, are furnished with square studs of iron set in rows, which are so disposed that the pins of one roller do not come in contact with those of the other, but pass immediately between or beside them. It is obvious from this arrangement, that an apple thrown between these cylinders, turning in contrary directions, will be *torn* into minute pieces in a moment; but the uniform pulp which is so desirable cannot be attained in this manner, and it is even common to beat the fragments, after coming from the mill, with wooden pestles.

Fig. 307.



Pressing.—When the fruit has been sufficiently ground, the uniform pap produced is removed from the mill and thrown into vats, where it remains for twenty-four, or, according to DUMAS, twelve hours. There can be no doubt that this procedure is attended with good results, and it is probable that sufficient importance is not attached to it, since many ciderists carry the pulp at once from the mill to the press. Even during the short process of grinding, the air changes the color of the mass to a deep red, though whether this is produced by the absorption of oxygen, or from the action of the constituents of the fruit upon each other, has never been accurately ascertained; it is most probable, however, that each cause has an influence depending on the other. Certain it is, that if the juice be at once expressed from the apples, it is a meagre, thin liquid, while that of the poorest fruit, when exposed for some hours to the air, becomes quite red, and runs sweet and luscious when, after being well ground, the pulp is submitted to the press.

After the time which may be thought sufficient has expired, and when a slight degree of fermentation is observable, the pulp is put into hair-cloths made for the purpose, each of which is from three and a half to four and a half feet square, and, when the sides are raised and folded over the contents, about six inches thick.

Formerly mats made of reeds or straw were employed to retain the pulp during the expression of the juice, but they have long been laid aside, as they were, on the whole, more costly and far less convenient than the kind now in use.

Presses on many different systems are now in operation. One would naturally incline to employ only those which, without being too expensive in their first construction, perform well, and with little friction. These are not the qualities, however, which distinguish most of the presses of the present day. It is reasonable to suppose, that in an establishment where much cider is produced, vertical, or, better still, horizontal hydraulic presses might be used with advantage; more juice would thus be obtained from the same quantity of fruit, and the manual labour would be considerably diminished. In default of these, iron screw presses might be substituted; indeed this is the kind most commonly employed.

With the ordinary presses the extraction of the sap cannot be completely effected at one operation; it is necessary to pass the *marc* a second time under the wheel, or between the rollers, and then to proceed to an additional pressing, which is said by some to be rendered more productive by adding to every two hundred and twenty pounds of the material about eleven gallons of water, which, acting by displacement, renders easier the extraction of the last portions of juice. Usually the produce of the two pressings is mixed, and thus forms a liquid of medium quality.

Fermentation.—This may be termed the most important of the operations required for the production of good cider, though it is often greatly neglected, and even entirely omitted by some farmers, in making cider for their home consumption. The nature of the decompositions occurring are only very partially understood, and there are few processes which have been, and still are, carried on with so little aid from chemical science.

Mr. J. C. KENT, of Upton-on-Severn, says, it is quite impossible to express in words the directions necessary for the management of the fermentation in cider or perry. The liquid is so capricious, that only those who have practically watched it can judge when it must be racked, or left at rest, *et cetera.*

The juice is generally received, as it flows from the press, into a stone cistern sunk in the ground immediately underneath, and is thence conveyed to the cellar, where it is usually turned into hogsheads of a hundred gallons each, leaving a few gallons ullage. Casks containing two, three, or even four hundred gallons are frequently used, and they are preferable of that size, especially after the liquor has become *bright*, and all active fermentation has ceased. Long ranges of casks are, in abundant seasons, placed on trams, and allowed to remain for a considerable period in the open air; where, unless the weather be very severe, the *working* proceeds as well as in that removed to the vaults. In about forty-eight hours—more or less, according to the temperature of the weather, *et cetera*—after the cider has been turned, the feculent parts of the fruit, which have passed with the juice through the hair-cloths, separate from the fluid and are thrown to the surface. When this occurs no time should be lost in racking the liquor, for, if taken at this juncture, it runs off perfectly bright; but should it be neglected, the internal motion occasioned by the fermentation causes the extraneous matter to again mingle with the liquid. After the lapse of a few days it subsides to the bottom, though when the weather is mild and warm this period is protracted, and the product is in proportion deteriorated.

If it is intended that the cider should attain the highest perfection of which it is capable, it must be carefully watched to prevent any active fermentation; should this occur, it must be again racked, and this treatment continued until perfect quiescence ensues. The fewer the rackings required the better will the cider be, for at each change of the vessel a portion of spirit evaporates, and, if repeated too frequently, the liquor is rendered poor and thin. In this lies the great art of managing cider; and, in warm seasons especially, it is still a desideratum to discover some means of checking a too rapid internal motion of its constituent particles, which is always induced by an increase of temperature. When it has remained quiet for some time, and shows no disposition to re-ferment or *fret*, if not perfectly bright—which it seldom is—it should be fined with isinglass, which may require to be repeated two or three times ere the maximum transparency is obtained: the cask may then be stopped down close, but must be occasionally examined. It is usual to heighten the color of the cider by the addition of a little caramelised sugar.

Every time the liquor is racked, a quantity of lees will be found; they are generally put into *dropping-bags*, which retain the feculence, while the fluid portion runs off clear. By some this is kept separate from the body of the cider, because of its having become flat by exposure to the air, both while draining from the bags and in the receiving tub, while others return it to the cask, as having a tendency to arrest the fermentation.

Sometimes a minute quantity of bullock's blood is mixed, while warm from the animal, with the lees, previous to their being put into the bags, and is said to contribute, by its coagulation, in aiding the separation of the liquor. From this circumstance the merchants have been unjustly accused of *doctoring* their cider—that is, of giving it, when in an unsaleable condition, the specious appearance of soundness—with bullock's blood.

BOTTLING.—With the merchants, the time for putting cider into bottles is in the spring following the season in which it is made; and it is common to mix with it a portion of old and sound liquor of the previous year's growth, to prevent the loss of the whole by a continuation of the fermentation, and the consequent bursting of the bottles.

When not intended for sale, it may remain till the autumn, and may then be safely bottled without admixture; but the largest quantity being consumed in the summer months, it is absolutely necessary that, when intended for the market, the bottling should be done about the month of March.

Properties.—The properties of cider have never been attentively observed. The Editor believes them to resemble, in their influences, the Rhenish wines. Amid all the differences in the qualities of cider, owing to the variety of the fruit from which it is produced, the nature of the soil, the method of manipulation, and many other circumstances, there are certain general chemical characters in which all ciders agree. They contain little extractive or solid nutritious matter; no bitter or narcotic ingredient has been added to them; they contain, on an average, about eight per cent. of alcohol, being similar, in point of strength, to the common hock, the weaker champagnes, and the better English ales. They are also distinguished from malt liquors by containing lactic instead of acetic acid.

Cider is further characterised by the great facility with which it becomes sour or acid; hence the frequency of its being *hard*, the difficulty of transporting it unchanged from place to place, and the disappointments which attend the efforts to keep it sound for any length of time.

It was remarked, during the continuance of the cholera in England, both in 1832 and in 1849, that the counties of Devonshire and Herefordshire were singularly free from that fearful disease, although the adjacent ones were visited by it in much the same degree as any other part of the kingdom. This has been attributed by some to the extensive consumption of cider; but the action of such a cause appears extremely improbable, since most wines and fermented liquors are known to produce a contrary effect. It does not, however, like malt liquors, cause flatulence, and it is an agreeable, gentle aperient, very salutary in warm seasons. The aqueous, oily, and vinous principles are so admirably blended, and the whole is so imbued with the grateful flavor of the rind, the aroma of the pulp, and the bitter of the seeds, that, when matured by time, the liquor becomes both delicious and wholesome.

PERRY.—*Poire*, French; *Birnwein*, German—is made from the juice of pears, in exactly the same manner as cider from apples.

The following is an analysis of the ripe fruit by Berard:—

	Centesimally represented.
Water,	86·25
Grape-sugar,	6·45
Vegetal fibre,	3·80
Gummy matter,	3·17
Malic acid,	0·14
Albumen,	0.08
Chlorophyl,	0·08
Ash,	0·03
	100·00

Besides these appreciable substances, the pear affords traces of pectic and gallic acids, fatty and essential oils, nitrogenous matters and carbonic acid. From the above analysis, it will be seen that it contains more saccharine matter than the apple; the liquor produced from it is, consequently, richer in spirit.

The pear gives, when incinerated, 0·41 per cent. of ash, the composition of which, as ascertained by Richardson, is annexed:—

	Centesimally represented.
Potassa,	54·69
Soda,	8·69
Lime,	7·98
Magnesia,	5·22
Sulphuric acid,	5·69
Silicic acid,	1·49
Phosphoric acid,	14·28
Phosphate of sesquioxide of iron,	1·96
Chloride of sodium,	trace.
	100·00

The action of perry on the animal system being more powerful than that of cider, has led to the belief that it was less wholesome. It is very agreeable to the taste, and approximates more nearly to cider than most white wines. On an average, it contains about ten per cent. of alcohol.

Adulteration.—Cider and Perry are often mixed with various coloring matters, but as these are almost universally inert, any particular notice of them is deemed unnecessary.

Cider which has been kept for a long time, or been badly fermented, frequently contains so large an amount of acetic acid, that it would be prejudicial if taken in this state. In that case it is often made to resemble new cider by the addition of an alkali, or of chalk. The latter may readily be detected by oxalate of ammonia, which immediately gives *a white precipitate*, indicating the presence of lime. A slight turbidness takes place with this reagent even in unadulterated cider, because it naturally contains salts of this earth, but in such very small quantities that the opaqueness is scarcely discernible. Potassa may be discovered by pouring into the suspected liquid a few drops of bichloride of platinum, evaporating to dryness on a water-bath, and acting upon the residue with alcohol. If a yellow insoluble precipitate remains, this alkali is denoted; but it must be remarked, as in the case of lime, that cider spontaneously includes salts of potassa, and will invariably yield a yellow compound—potassio-chloride of platinum—when treated as above; yet, in genuine cider, this is very small in comparison to that produced by the sophisticated article.

Lead, in the state of oxide or carbonate—litharge or ceruse—is mixed with cider, with the view of correcting acidity. This practice cannot be too strongly condemned, as any solution containing this metal acts most prejudicially upon the system. It is only very lately that the Editor had to examine a beverage which had caused most serious inconvenience to a whole family, inducing colics, bilious obstructions, and other dangerous complaints; it was found to be contaminated with a very notable amount of lead.

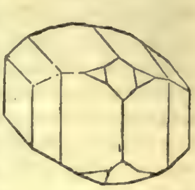
To detect this poison, evaporate the cider to dryness, and cinerate the residue; then dissolve in hot weak nitric acid and filter, and transmit through the filtrate a current of sulphide of hydrogen, which will produce a black coloration or precipitate, depending upon the quantity of the adulterant, if lead be present. This test is so delicate, that the one-fifty-thousandth of that metal may be thus revealed.

Upwards of two thousand years ago, it was known that lead had a most injurious effect on the animal economy. The ancients were very scrupulous as to the use of anything containing this metal; its presence in articles of daily consumption is to be dreaded, for many, by misplaced confidence, have arrived at an untimely end, or at least have been afflicted with that disease termed the Devonshire or painter's colic, and in numerous instances paralysis has been the final result. Indeed, many deplorable cases have been known of individuals being poisoned by this pernicious agent. Vile adulterations are not to be stopped by heavy penalties and stringent laws, means which have failed; but the only true remedy is the extension of chemical knowledge.

CITRIC ACID.—*Acide citrique*, French; *Citronsäure*, German; *Acidum citricum*, Latin.—This acid was discovered by Scheele in 1784. It exists ready formed in the juice of most ordinary fruits, as the lemon, orange, currant, *et cetera*, and in the sap of many plants. Citric acid is procured from lemon and lime-juice—in which it is especially abundant—as follows: the juice is sometimes submitted to an incipient fermentation, with the view of separating mucilage, which deposits, and the supernatant clear liquor is then poured off for use, or the juice is heated, and clarified by white of egg; it is then saturated at a temperature near its boiling point with very finely-powdered carbonate of lime, which is added in small portions as long as effervescence takes place, sixteen parts of the juice requiring about one part of the earthy carbonate. It has been noted, that owing to the formation of an acid salt of lime, the elimination of carbonic acid ceases before the whole of the citric acid is precipitated; in order to effect which, small quantities of hydrate of lime may be added till the menstruum no longer manifests an acid reaction; it is then permitted to cool, and the citrate of lime separated upon a strainer, and well aspersed with warm water till the percolating liquor runs off clear and colorless. Mr. G. J. Firman informs the Editor, that neutralizing with hydrate on the large scale interferes with the working, and no good result accrues from its use. The contents of the strainer are then decomposed by placing them in a hot mixture of one part of strong sulphuric acid diluted with six parts of water. Care must be exercised in this part of the process, so as to mingle intimately the lime salt and acid by constantly stirring them. When the mixing is completed, the whole is left at rest for several hours, until the decomposition of the citrate is complete; the clear solution is then decanted from the deposited sulphate of lime, which is washed with a little cold water. The citric liquor is then evaporated till it acquires the specific gravity 1·13, after which steam-heat or a water-bath must be used, so as gradually to expel aqueous vapor. As soon as the liquid becomes sirupy, or a pellicle forms on its surface, the heat must be withdrawn, to prevent any empyreuma. In about four days the mother lie is poured off the crop of crystals, and evaporated with the same precautions as before, and this is repeated till *clean* crystals are no longer obtained; the remaining liquor is then diluted, and submitted to the same treatment as the original lemon-juice. Several solutions and crystallizations are required to obtain the citric acid pure; in fact, it may be necessary to filter it through animal charcoal.

Currants have been recommended as a source of this acid: they are to be bruised, the expressed juice fermented, and then distilled to yield alcohol; the residue saturated with chalk, and the citrate of lime decomposed by sulphuric acid. One hundred pounds of this fruit afford ten pounds of spirit, and one pound of citric acid. This acid forms regular transparent rhombic prisms, the extremities of which are terminated by four trapezoidal faces, and which belong to the right prismatic system—see Fig. 308. They are of an intense acerb and agreeable taste, soluble in about their own weight of water at 60°, and in half their weight at 212°. They dissolve also in alcohol, but not in ether. Their diluted aqueous solution soon becomes mouldy. Anhydrous citric acid, as it exists in citrate of silver, for example, has not as yet been isolated. It is composed of—

Fig. 308.



		Centesimally represented.
12 Eqs. Carbon,	72	43·636
5 Eqs. Hydrogen,	5	3·030
11 Eqs. Oxygen,	88	53·334
1 Eq. Citric acid,	165	100·000

The acid obtained by subjecting to a heat of 212° the crystals deposited by a saturated cold solution, contains—

1 Eq. Citric acid,	165	85·94
3 Eqs. Water,	27	14·06
	192	100·00

The ordinary crystals from a hot saturated solution afford—

1 Eq. Anhydrous acid,	165	82·09
4 Eqs. Water,	36	17·91
	201	100·00

By spontaneous evaporation from a strong cold solution—

1 Eq. Anhydrous acid,	165	78·57
5 Eqs. Water,	45	21·43
	210	100·00

Citric acid, then, being *tribasic*, may be represented by the formula—

$$3\ HO,\ C_{12}\ H_5\ O_{11};\ =3\ HO,\ Ci.$$

By the action of concentrated sulphuric acid in the heat, citric acid is resolved into carbonic acid, carbonic oxide, acetic acid, and water, the elements of which it contains; and when it is fused with an excess of caustic potassa, it is split into oxalic and acetic acids and water, which is merely a different arrangement of the same elements, as shown in the subjoined equations:—

2 Eqs. Acetic acid,	$C_8\ H_6\ O_6$
2 Eqs. Carbonic acid,	$C_2\ O_4$
2 Eqs. Carbonic oxide,	$C_2\ O_2$
2 Eqs. Water,	$H_2\ O_2$
1 Eq. Citric acid,	$C_{12}\ H_8\ O_1$

In the latter instance—

2 Eqs. Acetic acid,	$C_8\ H_6\ O_6$
2 Eqs. Oxalic acid,	$C_4\ O_6$
2 Eqs. Water,	$H_2\ O_2$
1 Eq. Citric acid,	$C_{12}\ H_8\ O_{14}$

When citric acid is heated with peroxide of manganese, mechanically suspended in water, carbonic acid and acetic acid are formed; with red oxide of mercury, it produces effervescence, with the production of acetic acid; and with chloride of gold, reduction occurs without any evolution of gas. In fact, by oxidizing agents in general, citric acid is partially converted into acetic acid.

A few drops of citric acid added to lime-water produce no apparent effect until the mixture is boiled, when a white powder deposits, soluble in acids without effervescence.

The action of heat on citric acid has occupied the attention of many chemists, among whom may be mentioned LASSAIGNE, DUMAS, BERZELIUS, and ROBIQUET, all of whose experiments were different, and therefore contradictory and irreconcilable. The recent researches, however, of CRASSO have cleared up the whole matter, and reconciled the inconsistencies of his predecessors. According to this chemist, crystallized citric acid, when exposed to heat, exhibits four stages of decomposition. During the first, only the water of crystallization is expelled. The second stage is characterised by white vapors, and the production of acetone, carbonic oxide, and carbonic acid, while the residue consists of aconitic acid, which is therefore the true *pyrocitric acid.* In the third stage the aconitic acid, being fixed, is itself decomposed, yielding carbonic acid and an oily liquid which soon crystallizes—*itaconic acid.* In the fourth period empyreumatic oil is produced, and a voluminous charcoal remains. CRASSO further shows that the aconitic acid, heated *per se*, is converted into itaconic acid and carbonic acid; and that the itaconic acid, in the heat, affords a volatile acid isomeric with itself, which he proposes to call citraconic acid, and which always more or less accompanies the former, owing to its easy decomposition. The action of heat, consequently, gives rise to three distinct acids in regular sequence:—

Aconitic or pyrocitric acid;
Itaconic or pyroaconitic acid, and
Citraconic or pyroitaconic acid.

Raw lemon juice is extensively imported into England from Messina for sea-going purposes, every vessel, under the *Mercantile Marine Act*, being compelled to carry so much per man. Annexed are analyses, by the Editor, of different samples of the article, as received by Mr. ROBERT THIN of Liverpool, the largest importer in Great Britain, and who has generally twenty thousand gallons as stock:—

	Centesimally represented.		
	1851.		1852.
Citric acid,	6·01	..	7·18
Alcohol,	5·47	..	5·97
Inorganic salts,	0·53	..	0·61
Water, *et cetera*,	87·99	..	86·24
	100·00		100·00

The *concentrated* lemon juice, as used by the citric acid manufacturer, will keep for a very long time unaltered, but the *raw*, which is intended for ships, is always fortified with spirit, to arrest fermentation.

The analysis of the lemon juice of 1851 is a fair average quality, that of 1852 is somewhat superior; but this difference may be accounted for in this manner, that the lemons expressed in the early part of the season contain more citric acid, and as the season advances the water is a per cent. or two higher. Naples lemon juice is better than that from either Messina or Palermo, standing nearly equal in quality and flavor to Jamaica lime juice, which is principally used by the preparer of cordials.

Sir WILLIAM BURNETT recites several trials that were made, on voyages, with lemon juice and citric acid. It appears that the latter was, *in many instances*, useful as a remedy, but that the former was *generally* of service both as an antiscorbutic and a prophylactic. It is well known, however, that the lemon juice supplied has for many years been very inferior in quality; and as this had proved the case in some late voyages, it was decided to try the effect of lemon juice procured from the fruit squeezed in this country, and in the fitting out of the late Arctic Expedition, and that to Behring's Straits, *et cetera*, this was carried into effect.

It was determined that one-half of the juice intended for the Northern expeditions should be slightly boiled, then strained, and, lastly, after being allowed completely to cool, bottled, bringing the juice in the bottle up to the neck; a small quantity of the best olive oil was then poured over it, and the bottle corked and sealed. The other half was prepared by adding ten per cent. of brandy, bottled, and oil poured over it in the same way. BURNETT states that both these experiments proved eminently successful, and there never was lemon juice so thoroughly preserved in all its qualities; and after being a winter in the Arctic Seas, it still retained its virtues unimpaired: not one case of scurvy occurred in any of the ships of war during *the nineteen months* they were absent.

MANUFACTURE.—This acid is fabricated by a few firms from the juice of lemons, which is imported, in a concentrated state, principally from Sicily in casks, containing each from one hundred and five to one hundred and ten gallons. It is often adulterated with acids, common salt, *et cetera*, the former of which, were it tested by the amount of alkali a certain quantity would neutralize, would give a good per centage; while the former is added to increase the specific gravity, since, in many establishments, it is examined by means of the *citrometer*—which is nothing more than a hydrometer, marked for this particular purpose—and thus the same object is attained. The density of the juice is also often rendered much greater by the carbonization which has occurred during its evaporation; thus, for these reasons, and also on account of the variation in the amount of earthy salts and of saccharine matter, the specific gravity test can scarcely give an approximant result as to the real quantity of acid contained in the sample. Even the neutralization of a certain weight of alkaline carbonate is a doubtful means of estimation, for the reasons above mentioned, unless the juice has been previously examined for other acids, and their per centage ascertained.

The citric acid contained in the ordinary concentrated juice is about thirty-two per cent.

The process followed for its facture on the large scale, does not essentially differ from that of preparing small quantities, except as regards the utensils.

Fig. 309 is a view of the principal room of that part of the factory of Messrs. **Firmin** and **Son**—of London and Newton-le-Willows, Lancashire—devoted to the production of citric and tartaric acids, the processes of which are similar in every respect.

The juice to be operated upon is conducted into the decomposing tuns, A A, by tubular pillars, B B, provided with stopcocks, which communicate with cisterns in the apartment above, into which the contents of the casks are emptied. When the tuns are sufficiently filled, decomposition of the juice is effected with a sufficient quantity of carbonate of lime, previously well ground, and the agitators are kept in constant motion by the machinery above the tun, worked by steam power.

Fig. 309.

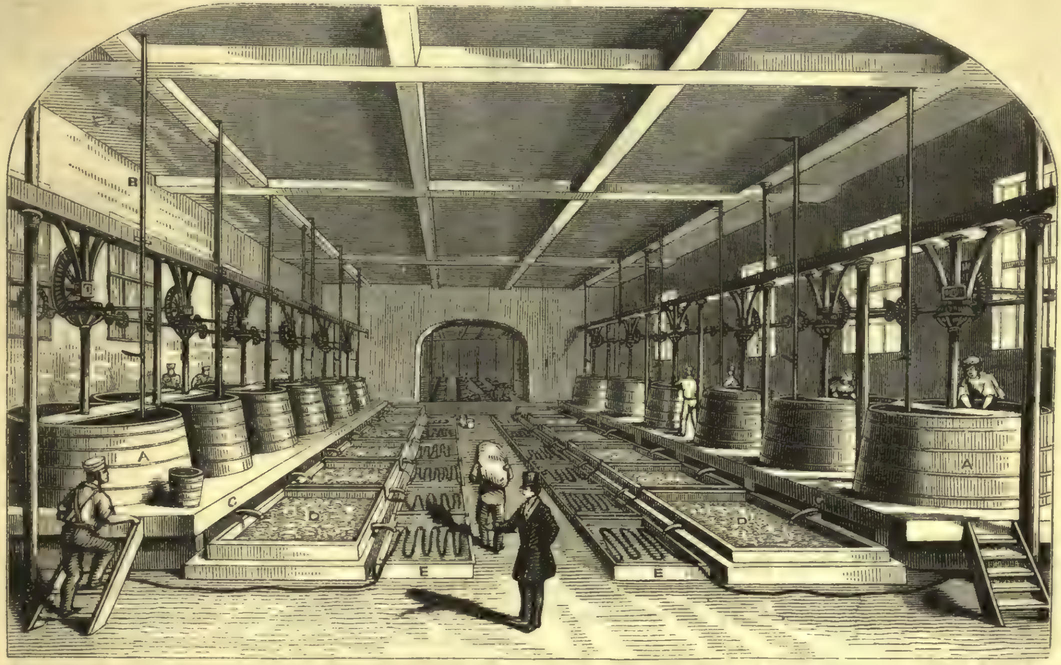
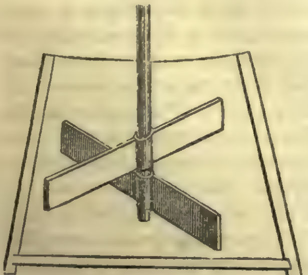


Fig. 310 is a section of the tun, showing the agitators in the interior.

After as much as possible of the citric acid, contained in the juice, has united with the lime, and the precipitate has subsided, the supernatant liquid is drawn off, and the citric acid set free by an addition of sulphuric acid.

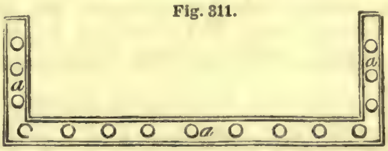
The whole contents of the tun are finally run off by the pipes, C C, into the vats, D D, which retain the sulphate of lime, while the solution of citric acid flows into the steam evaporators, E E, where it is concentrated.

Fig. 310.



One of these evaporators is shown in section in Fig. 311, in which the two inner lines represent the lining of lead, and the outer ones the exterior casing of wood, while the circles indicate steam-pipes in the interior; besides these, however, flexible tubing for the conveyance of heat traverses the liquor repeatedly, as shown in Fig. 309.

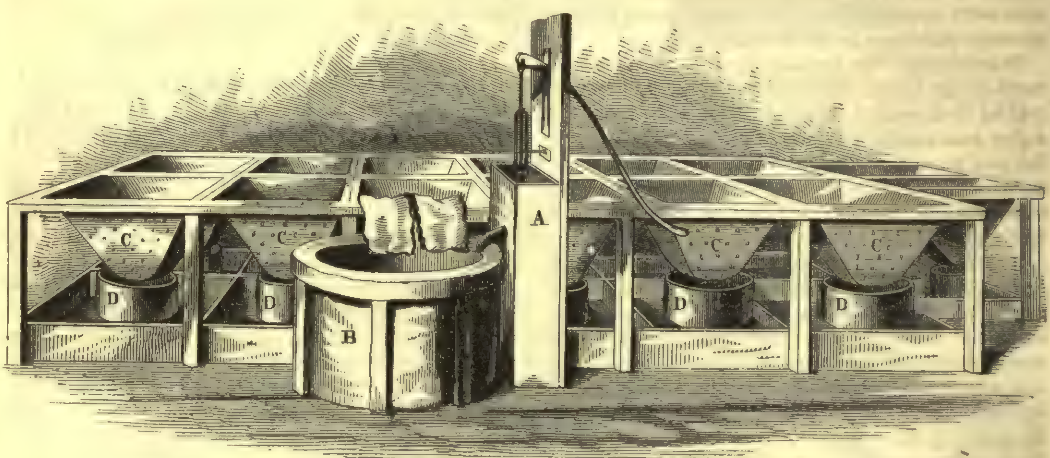
Fig. 311.



When the evaporation has been sufficient, the solution is drawn off by means of the pump, A—Fig. 312—into the cistern, B, whence it is put into lead pans, similar to D, and allowed to crystallize. The supernatant liquor is then withdrawn for further concentration, the crystals dissolved, and the solution ladled into the filters, C C, which are lined with lead, the sides being pierced in numerous places. Each of these is supplied with a quantity of animal charcoal, which not only decolorizes the fluid, but deprives it of its mechanical impurities. On percolating, it is received into the crystallizing pans, D D, in which it is allowed to stand until the crystals cease to form, or do so only very slowly. The mother liquor is again returned for evaporation. Two or three re-solutions and crystallizations may be requisite to obtain an article of superior size and purity.

The carbonization of the acid during its evaporation, is an extremely annoying occurrence. Numerous plans have been devised for its prevention, but all have been relinquished for steam-heat; and even this is often too powerful, as the brown coloration of the solution, and the empyreumatic odor in the room in which the concentration is carried on, testify.

Fig. 312.



In the manufacture of citric acid, the observation has been a long time since made, that citrate of lime cannot be preserved. It decomposes, and no longer yields citric acid—carbonic acid resulted as a product of the decomposition, which remained behind in combination with the base, but the nature of the change was no further known. **Personne** has closely examined the metamorphosis. He finds that it is a true fermentation, in which the citric acid is split into acetic, butyric, and carbonic acids, under the evolution of hydrogen.

When clarified lemon juice is saturated with lime, and then a glass tube introduced into a closed vessel containing this mixure, in the course of two days, at a temperature between 86° and 95°, gas is eliminated, and this continues until the citrate is completely changed. Crude lemon juice undergoes this decomposition much quicker. But citric acid is still more speedily decomposed, if mixed with citrate of lime and beer yeast.

The liquid in which the citrate of lime disappears, acquires gradually the disagreeable odor of the butyric fermentation. It evolves a mixture of carbonic acid and hydrogen, in which the relative proportion of one gas to the other, from the beginning to the end of the process, continually alters. The acid of the lime salt, which is dissolved in the liquid, and is obtained by evaporation, and then transferred to oxide of silver, affords two different salts, butyrate and acetate of silver. The formation of these acids may be explained by the annexed equations :—

$$4\,(3\,HO,\ C_{12}\,H_5\,O_{11}) + 4\,HO = 3\,(HO,\ C_4\,H_3\,O_3) + 2\,(HO,\ C_8\,H_7\,O_3) + 20\,CO_2 + 8\,H.$$

Four equivalents of citric acid and four of water, giving three of acetic, two of butyric, and twenty of carbonic acid, while eight equivalents of hydrogen are evolved.

In different states of purity, citric acid is used extensively by calico-printers. In medicine it is employed as a substitute for lemon juice, in the preparation of refrigerant drinks and effervescing draughts, and as an anti-scorbutic, anti-narcotic, and anti-alkaline.

As regards its physiological effects, there are various opinions. **Orfila**, for example, ranks it among the irritant poisons, while **Christison** and others gave drachm doses of it to cats, without observing that the animals suffered any inconvenience. Small quantities of it in water form an agreeable beverage, which allays thirst, diminishes preternatural heat, checks profuse perspiration, and promotes the secretion of urine.

Adulteration.—Citric acid and lemon juice are sometimes adulterated with tartaric acid, and to a very large extent. A sample analyzed by the Editor some months ago, contained an incredible per centage of the latter. The best way to detect this fraud when the sophistication is considerable, is to dissolve a given weight of the acid in water, and to add gradually to it a solution of potassa, stirring briskly; granules of bitartrate of potassa will fall or appear on the sides of the vessel, if any appreciable amount of the adulterant be present. If the quantity of tartaric acid be small, the solution of citric acid must be concentrated, and, instead of employing potassa, chloride of potassium, or nitrate of potassa—all of which are serviceable when delicacy and accuracy are not required—use the acetate of potassa, which, being deliquescent, may be added at once, without being dissolved, to the suspected solution.

When citric acid attracts moisture on exposure to the air, it is a proof that it retains a small portion of the sulphuric acid used in its preparation, which is very readily detected by dissolving in water, adding hydrochloric acid and chloride of barium. If a white precipitate or milkiness occurs, sulphuric acid is present. Re-crystallizing several times will at once purify it. Tartaric and sulphuric acid are often mixed with the raw lemon juice; and it is a fact, however unpleasant to mention, that hundreds of ships sail from Liverpool and London with an article sophisticated with *oil of vitriol, et cetera.* Mr. THIN remarks, that this adulterated article, on account of its intense acidity, meets with more approval from the common palate than the agreeable acerbness in the genuine juice.

STATISTICS.—The quantity of citric acid manufactured in the United Kingdom varies considerably according to demand. It may be stated at from sixty to eighty tons yearly, and the price has ranged, during the past three years, from one and eightpence to five shillings per pound. Messrs. FIRMIN'S annual make is from thirty to forty-five tons, half of the total weight fabricated. Their establishment is well worth a visit.

COBALT.—*Cobalt*, French; *Kobalt*, German; *Cobaltum*, Latin.—The word cobalt seems to be derived from *Cobalus*, a malicious sprite or gnome, that, according to the superstitious ideas of the times, haunted mines, destroyed the labors of those working them, and often caused them a deal of unnecessary trouble and annoyance. It is probable that the miners gave the name to the mineral in jest, because it annoyed them as much as the supposed spirit, by exciting false hopes, and rendering their toil often unprofitable. It was once a custom in the Church to utter a prayer for the protection of miners and their works against *kobolts* and spirits.

Though there is no doubt that the process used in the preparation of cobalt was invented about the beginning of the nineteenth century, one has reason to ask whether the ancients were acquainted with this metal, and if they employed it for any particular purpose. They opened and worked mines in various parts; and it is possible, as BECKMANN observes, they might have found cobalt. Many successful attempts were made to impart different hues to glass, and *blue* glass and *blue* enamel were, it is well known, produced. This might have been learned accidentally, as was the case with the making of brass; and the azure glass might, perhaps, have been fabricated as long as the colored earth lasted; the process, after this occurrence, being lost in oblivion, till the modern chemist, by investigating the subject, placed at the disposal of the artist definite compounds, by which certain results are always insured.

GMELIN has proved by chemical experiments, that it is not only possible to give to glass and enamel a blue color by means of iron, but that several of the antiquities, upon which so much stress has been laid, afford not the slightest indication of cobalt. He even made some observations on the tiles found in a Roman tessellated pavement, and likewise on the blue paint of a mummy. He mentioned also several articles on which a blue color is produced by the vitrification of iron—of this nature are, in particular, those slags found near the smelting mines in the Hartz forest, some of which are of a beautiful blue color. The ancients may have been induced, from the blue slags of their smelting-houses, to make experiments on the coloring of glass with iron, and in this art they acquired a proficiency not now possessed, because it was abandoned after the invention of smalt, which has a finer appearance, and can be used more easily, and with greater certainty. The use of anything does not imply a knowledge of its properties, for the moderns made brass and smalt—*a glass of cobalt*—many centuries before they ascertained how to prepare zinc and regulus of cobalt.

The ancients could describe minerals in no other way than by their exterior aspect, so that it can scarcely be expected that cobalt can be discerned with any degree of certainty among those mentioned by them. It is well known now, that there is no species more changeable in its outward form than cobalt ore, and nothing could better demonstrate the impossibility of distinguishing minerals with correctness by external features. The meaning of the term *cadmia* is as uncertain as cobalt was two centuries back. It signified often calamine—carbonate of zinc—sometimes furnace dross, *et cetera;* but BECKMANN says it was never applied to cobalt till mineralogists wished in modern times to find a Latin term for it, and assumed that which did not properly appertain to any other mineral. GMELIN appositely observes, that the strong and disagreeable mixtures arising from cobalt would, had it been known, have induced the ancients to make particular mention of it in their writings. Would not the arsenic, which is so often combined with it, have given occasion to reports respecting the dangerous properties of these minerals? And would not arsenic and bismuth have been sooner known, had preparations of cobalt been made at that early period?

A mineral called cobalt has been used in different parts of Europe since the fifteenth century, to tinge glass. The nature of it was altogether unknown till it was examined by BRANDT, the celebrated Swedish chemist, in 1733, who obtained from it a new element, to which he gave the name of cobalt.

PREPARATION.—This metal is never employed in the reguline state, so that the processes for its reduction are generally conducted upon a small scale, and confined to the experimental laboratory; indeed, there is very great difficulty in obtaining pure cobalt. The following are among the best processes for this purpose:—*Zaffre*, which is a very impure oxide of cobalt, is dissolved in hydrochloric acid by the aid of a little nitric acid, and sulphide of hydrogen transmitted through the solution, by which arsenic, copper, and other metals are precipitated; the filtrate may be boiled with a little nitric acid to further oxidize the iron, and precipitated by carbonate of potassa: the precipitate, when well washed, is to be digested in oxalic acid, which dissolves the sesquioxide of iron, and leaves an insoluble oxalate of cobalt; this may be decomposed at a high temperature, leaving oxide of cobalt, which is reduced when hydrogen gas is passed over it in a heated state.

WÖHLER'S process is, to mix one part of pulverized ore—speiss cobalt, or glance cobalt—with three parts of carbonate of potassa and three of sulphur, in a covered earthen crucible, and submit to a gentle heat, so that the sulphide of cobalt may not fuse: the product is well edulcorated with water, to separate arsenious sulphate of the alkali, and subjected to a second similar fusion, and affusion with water: it is then digested in nitric acid, to which dilute sulphuric acid has been added, and precipitated by carbonate of soda. The carbonate of cobalt, heated and reduced by hydrogen, gives a pure product. To obtain the metal from the arsenide, the ore, finely powdered, is gradually added to three parts of bisulphate of potassa, melted in a moderate heat, and by degrees increasing the fire till no more white fumes appear. The mass, when cold, is powdered, and boiled with water as long as anything is dissolved. The solution is free from arsenic, and contains protosulphate of cobalt. It is precipitated by carbonate of soda, and the washed precipitate acted on by oxalic acid, which forms an insoluble pink powder of oxalate of cobalt. Should iron be present, it gives a soluble compound with the oxalic acid, provided it has been brought into the state of sesquioxide, by boiling the solution with a little nitric acid previous to adding the alkaline carbonate. The only impurity now likely to be present is nickel, and to separate this, the oxalate is dissolved in an excess of ammonia, and the menstruum exposed to the atmosphere in a deep glass vessel. As the volatile alkali evaporates, this metal, if present, is deposited in the form of a pale green, insoluble, double oxalate of nickel and ammonia, while the cobalt remains dissolved, forming a port-wine colored solution, which being digested with an excess of potassa, yields a dark-brown precipitate of pure oxide of cobalt. This is again dissolved in hydrochloric acid, the solution precipitated by *aqua potassæ*, or carbonate of soda, and the precipitate converted into oxalate, which is now quite pure; the latter, heated to whiteness in a closed crucible, having a small orifice, to allow any gas to escape, leaves a button of pure metallic cobalt. The oxalate of cobalt is resolved by the heat into carbonic acid and metal—

$$\mathrm{Co\,O,\,C_2\,O_3 = Co + 2\,C\,O_2}.$$

PROPERTIES.—Pure cobalt is of a grey color, with a shade of red, and by no means brilliant. Its nature varies according to the temperature employed in fusing it. Sometimes it is composed of plates, sometimes of grains, and occasionally of small fibres adhering to each other. It is almost devoid of taste, has a specific gravity of 7·834, and is not magnetic. Its equivalent is 29·5. When exposed to the air it undergoes no change, neither is it altered when kept under water. When sustained at a red heat in an open vessel, it slowly imbibes oxygen, and is converted into a powder, at first blue, but which gradually becomes deeper and deeper, till at last it assumes a blackish hue. If the heat be very strong, the cobalt takes fire, burning with a reddish flame. It unites in several proportions with oxygen, but the protoxide is the only one of particular importance in the arts. It is formed by adding potassa to the nitrate. The precipitate has a blue color, but when dried in the air it acquires a blackish tinge. The protoxide may also be obtained by heating the carbonate of cobalt out of contact with the atmosphere; it is then of a greenish-grey color. It is recognised by the facility with which it imparts a blue tint to vitrifiable compounds and to white enamel.

Any compound of this metal may be at once recognised before the blowpipe, by fusing it with borax in the loop of a platinum wire for some seconds. If cobalt be present, even with other substances, a beautiful blue bead will result from the experiment, which is an infallible proof of its presence. Protoxide of cobalt dissolves with evolution of heat in nitric and sulphuric acids; and is known to be free from higher oxides, by not giving chlorine when treated with hydrochloric acid. Its solution in this acid, when concentrated, is bluish green, but if diluted with water it is pink. When hydrogen is poured over it at a red heat it is decomposed, and metallic cobalt remains, which, if pure, cannot be exposed to the air without taking fire. If it does not ignite, it proves the presence of a trace of nickel. Protoxide of cobalt consists of—

		Centesimally represented.
1 Eq. Cobalt,	29·5	80·00
1 Eq. Oxygen,	8·0	20·00
	37·5	100·00

The coloring power of oxide of cobalt is so intense, that pure white glass is rendered sensibly blue by the addition of one-thousandth part of the oxide; one twenty-thousandth of oxide communicates a perceptible azure tint.

Chloride, nitrate, and sulphate of cobalt, form what are termed *sympathetic inks*. Thus, if characters be written on paper with the chloride, they remain colorless and invisible; but, by holding the sheet to the fire, the writing appears brilliantly blue. As the paper cools, moisture is absorbed, and the color disappears, but may be reproduced by heat. The addition of a salt of nickel gives a green instead of a blue hue; consequently, in painting what are called *magic landscapes*, the sky is limned with pure chloride, and the trees and grass with a solution containing nickel.

Nitrate of cobalt is a red sympathetic ink.

Phosphate of cobalt—an insoluble precipitate, having a deep violet color—is obtained by adding a solution of phosphate of soda to a dissolved salt of the oxide. Two parts of phosphate and one part of arseniate of cobalt, carefully mixed with sixteen parts of alum, and strongly ignited for some time, afford the beautiful blue pigment—*Thenard's blue*—which is said to possess all the characters of ultramarine.

Aqua potassæ produces a blue precipitate in solutions of cobalt, which becomes green, and if boiled, or long kept, dirty red—owing, of course, to different gradations of oxidation. It is not redissolved in an excess of the precipitant. Ammonia affords a blue precipitate in solutions of cobalt, which, on its further addition, becomes green, and mostly dissolves; this assumes a brown tinge by exposure to air. Carbonate of ammonia produces a pink precipitate, which dissolves in excess, and also in chloride of ammonium. Ferrocyanide of potassium gives a bluish grey deposit. Sulphide of hydrogen *does not throw down the metal*, but sulphate of ammonium produces a black precipitate, even when the solution is very dilute.

ORES.—The principal cobaltic minerals are those designated arsenical cobalt, cobalt glance, cobalt bloom, cobalt pyrites, *et cetera*. *Arsenical cobalt* occurs chiefly in primitive rocks, accompanying ores of silver, bismuth, and copper, as at Freyberg, Annaberg, and particularly at Schneeberg, in Saxony; at Joachimsthal, in Bohemia; and at Huel Sparnon, in Cornwall. At Riechelsdorf, in Hessia, its veins are included in cupriferous shale; and the reticulated variety from Joachimsthal is frequently embedded in calcareous spar. Color tin-white, inclining, when massive, to steel-grey.

The following shows the composition of this mineral:

	Centesimally represented.	
	Riechelsdorf.	Schneeberg.
Cobalt,	20·31	28·00
Arsenic,	74·21	65·75
Iron,	3·42	—
Copper,	0·15	6·25
Sulphur,	0·88	—
Loss,	1·03	—
	100·00	100·00

Before the blowpipe on charcoal it emits copious arsenical fumes on the first impression of the heat; it fuses, however, only partially, and with great difficulty; to borax and other fluxes it imparts a deep blue color, and with nitric acid affords a pink solution.

Cobalt glance is met with in large, resplendent, distinctly-pronounced crystals, at Tunaberg and Hokensbo, in Sweden. It also occurs abundantly in mica-slate at Wehna, in Sweden, and at Modum and Skutterud, in Norway; less so at Querbach, in Silesia, and in the vicinity of St. Just, in Cornwall. From the preceding it may be distinguished by its inferior specific gravity and reddish hue; also, by its lamellar structure, its more distinct cleavage, and by its requiring considerably greater heat to drive off the arsenic. The cobalt, or smalt of commerce, is chiefly obtained from it. The color is silver or yellowish white, with a tinge of red. The following are analyses of it by Stromeyer and Klaproth:—

	Centesimally represented.		
	Skutterud.	Tunaberg.	Tunaberg.
Cobalt,	33·10	36·66	44·00
Arsenic,	43·47	49·00	55·00
Sulphur,	20·08	6·66	0·50
Iron,	3·23	5·66	—
Loss,	·12	2·02	0·50
	100·00	100·00	100·00

In the blowpipe flame it evolves plenty of arsenical fumes, and, after being roasted for some time, melts into a metallic globule, externally of a dull black, which attracts the magnet, but is not malleable; it tinges borax of a deep blue color, and effervesces in warm nitric acid.

Cobalt pyrites is found at Ridderhyttan, in Sweden, in grains, associated with copper pyrites and hornblende; and at Mussen, in Prussia, with baryta and carbonate of iron. Its color is steel-grey or whitish, with a tinge of yellow; massive, with an uneven fracture, presenting a granular surface, and botryoidal. Hisinger and Wernekinck analysed it, and found—

	Centesimally represented.	
	Ridderhyttan.	Mussen.
Cobalt,	43·20	43·86
Copper,	14·40	4·10
Iron,	3·53	5·34
Sulphur,	38·50	41·00
Loss,	0·37	5·70
	100·00	100·00

On charcoal, *per se*, before the blowpipe, it fuses, after roasting, into a grey metallic globule, from which it is difficult to expel the last portions of sulphur; with the fluxes, the effects of the cobalt predominate so much, that it is impossible to distinguish those of iron or copper. It is soluble in nitric acid, with the disengagement of nitrous gas, leaving a whitish residue. Neither in the analysis, nor before the blowpipe, does it indicate the slightest trace of arsenic.

Hofmann found in the *speiss-cobalt*, from Schneeberg, nearly two per cent. of nickel. The Editor is of opinion that nickel nearly always accompanies cobalt; but as their separation is so difficult, and the nickel is generally present in such small quantities, it has, till recently, been overlooked.

The value of cobalt ores varies extremely, and not only depends upon the centesimal amount of cobalt, but on their freedom from other metals, excepting nickel, and the presence of the latter in such quantity as will make the separation remunerative.

Manufacture.—The two compounds of cobalt in extensive demand in commerce, are the oxide and smalt—silicate of cobalt, *et cetera*—which will now claim attention.

Oxide of Cobalt.—In the preparation of the oxide on a large scale, the ores are smelted, and the regulus or speiss which they yield calcined. The resulting product is then dissolved in strong hydrochloric acid, and the iron and arsenic precipitated by the gradual addition of milk of lime. When the oxides have subsided, the clear supernatant liquor is run off, and subjected in vats to a stream of sulphide of hydrogen, produced by decomposing sulphide of iron, or, better and cheaper, the waste from alkali works, with hydrochloric acid, which throws down the copper, *et cetera.* When the sulphides have completely settled, the supernatant liquor is siphoned off, and the cobalt precipitated from it by bleaching powder—chloroxide of calcium. The hydrated oxide thus obtained, heated to redness, constitutes *the blue oxide*, and to whiteness, the *prepared oxide* of commerce.

These oxides are generally used in the potteries, and by enamellers and glassmakers, who mix them in variable proportions, either alone or in conjunction with other materials for imparting a blue tinge to their wares. They are principally made in Birmingham by the nickel refiners, and the price varies from fourteen to sixteen shillings per pound.

Smalt.—This preparation was invented about the year 1540, in Saxony, and has since been carried on as the only metallurgic process connected with the ores of cobalt.

In the analyses of the several minerals—which are rather arsenic than cobalt ores—given in the adjoining column, it will be seen that the cobalt in them is partly replaced by other elements. Arsenical cobalt, which is of more common occurrence than the other varieties, is always associated with a much larger proportion of the other metals, which are not only components of its chemical constitution, but accompany it as distinct minerals in the vein. The mechanical purification, which is a process of levigation, and precedes the working of the ore, does not separate these, which have about the same specific gravity as the cobalt ores themselves, but only the *matrix*, which, being lighter, is suspended in water, and is poured off while the ore subsides. **Knapp** states that the purer pieces are selected, and freed by the hammer from a large portion of the foreign minerals; the remainder is submitted to pulverization, and partially februated by levigation. An admixture of tin, antimony, or bismuth, communicates a yellow hue to cobalt glass, as does also oxide of zinc, when any considerable quantity is present. The color verges into violet with small quantities of nickel and copper, and becomes brown with a larger addition. The same effect is produced by protoxide of iron, which, however, when not in too great excess, is rendered harmless by the presence of arsenic as a decolorizing material.

The next object in this manufacture is to convert the cobalt of the levigated ores into oxide, in such a way that the foreign metals shall be separated or rendered inert. This is accomplished by roasting, and the oxide thus produced is then vitrified, with the addition of pearl ashes—carbonate of potassa—a little saltpetre, and fine sand—silica. It is, therefore, a potassa glass tinged with the silicate of cobalt. Several varieties or samples of it are kept by the manufacturer, which serve him as a guide, because, before commencing operations on a large scale, he makes sundry assays in the laboratory, and is thus enabled to judge, from the results of his small crucibles, how to apportion the materials in his glass furnace. The different shades of smalt known in commerce are distinguished under the names coarse blue, or *streublau, farbe, eschel;* the former is little used. The *farbe,* or azure, is the chief product, and is subdivided into numerous varieties, designated by letters; such as—

O U, Ordinary ultramarine.
M U, Middling, or medium ultramarine.
F U, Fine ultramarine.
O C, Ordinary cobalt, or azure.
M C, Middling cobalt.
F C, Fine cobalt, or azure.
F F C, Superfine cobalt.
F F F C, Extra superfine cobalt.

The various kinds of the *eschel* quality are similarly denominated; thus—

F E, Fine *eschel.*
F F E, Double fine.
F F F E, Triple fine.
F F F F E, Quadruple fine, *et cetera.*
O E G, Ordinary ground *eschel.*
F O E G, Fine ordinary ground *eschel.*

The *ultramarine* is remarkable for its fineness and beauty of shade; this product, however, has nothing but the name in common with the genuine article. *Azure,* properly so termed, has a color at least as intense as that of the ultramarine, but the grain is not so fine, and its tint is less pure. *Eschel* is less colored than the azure. Besides these three principal sorts, there is the compound called **Thenard's** blue, before mentioned.

In the cobalt works, it is evident that the object of the metallurgical processes is not to obtain a pure metal, but to prepare an oxide, in order to mix it in suitable proportions with vitrifiable substances, and to obtain, by the fusion of such, a glass possessing a good cerulean tint. It is this glass in fine powder which is extensively diffused in commerce.

Roasting.—During this process the sulphides of the ores absorb oxygen, sulphurous acid being formed, collaterally with oxides and sulphates of the metals, while the volatile arsenic is consumed and carried away by the draught as arsenious acid.

This manufacture is mostly pursued in winter, in order that the external cold may favor the more complete condensation of the acids of arsenic. The construction of the reverberatory furnace—Figs. 313 and 314—in which this operation is conducted, is adapted to collect these volatile and poisonous products. The arch, *c c,* and the sole, *a,* of the roasting-hearth are formed of fire-stone. From three to five hundredweight of schlich—pasty ore—are introduced by the roasting door, *b,* and serve for one operation; they are spread out in a uniform layer five or six inches in thickness, and this is then exposed to the flame of a fire on the grate, *r.* The flame passes over the fire-bridge, *n n,* and escapes with the volatile products through the flues, *o o,* into the common flues, *d d,* which encircle the fire-place. The orifices, *m m,* of these flues are only intended for the purpose of cleaning, and are usually closed; through the opening, *p,* on the contrary, the smoke enters a long smooth gallery—*poison gallery*—or a broad chamber sufficiently wide to impede the velocity of the draught, and allow the arsenious acid time to collect and deposit.

Fig. 313.

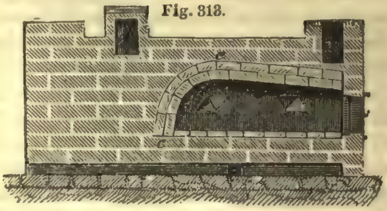
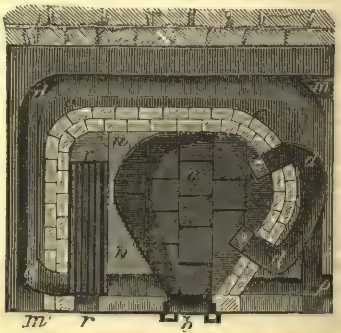


Fig. 314.



Should the ores be pure, the roasting must be continued until the oxidation of the metal is complete; not to do this would be disadvantageous, as the unchanged sulphide and arsenide of the metal would be decomposed in the subsequent fusion, at the expense of a portion of the alkali, into sulphide and arsenide of potassium and oxide of cobalt.

It is very different, however, with the impure ores as they are usually worked; nickel and copper would also be oxidized in this case by a complete process of roasting; and the oxides of these metals—which cannot be decolored, and thus rendered innocuous—would be associated with color and spoil the product, the nickel communicating a hyacinthine, the copper a florid red or green tint. It is, therefore, an obvious error to roast fully, or to dead-roast, ores of such a character, and this is carefully avoided in the smalt works.

When the ustulation is not carried beyond a certain point, arsenic remains behind on the one hand, and the oxygen absorbed is insufficient, on the other, to combine with all the metals which are competing for it: consequently, in the subsequent fusion, those metals—cobalt, iron, *et cetera*—which possess the most powerful affinity for oxygen will prevail, and retain it persistently, whilst the others—nickel, copper, silver, bismuth, arsenic, *et cetera*—with a less affinity for this element, will separate in the metallic state as regulus, or, combined with arsenic, as *speiss*, and collect below the layer of blue glass. If the roasting is continued for too short a period, a portion of the cobalt will remain unoxidized, and pass with the other metals into the speiss, when a loss of coloring matter will result; a small amount of cobalt in the speiss is, on the contrary, a good sign, indicating that the roasting has been sufficiently advanced, and yet that enough arsenic has been left to combine with the nickel, for which it has a stronger affinity than for cobalt. Arsenide of cobalt and oxide of nickel are mutually decomposed, by fusion, into oxide of cobalt and arsenide of nickel. The following constituents have been found in speiss:—

	Centesimally represented.		
	Berthier.	Will.	Wohler.
Nickel,	49·0	52·6	52·70
Arsenic,	37·8	40·5	44·00
Iron,	—	2·7	1·60
Copper,	1·6	1·6	
Manganese,	—	—	
Cobalt,	3·2	trace	—
Antimony,	trace	—	—
Sulphur,	7·8	2·5	1·65
Loss,	0·6	0·1	0·05
	100·0	100·0	100·0

Speiss is, therefore, a kind of artificial ore, consisting mainly of arsenic, nickel, and sulphur.

The product examined by WÖHLER comprised the crystals which are occasionally met with in speiss, and are obviously composed of three equivalents of nickel and one of arsenic—$Ni_3 As$—with an admixture of metallic sulphides.

When ores contain bismuth, as is the case with those of the Erzgebirge, the greater part of it is extracted before they are employed in the smalt works, and the remainder is subsequently found below the layer of speiss.

A small quantity of zinc adheres pertinaciously to the cobalt, and can seldom be totally removed; the oxide imparts a greenish tint to the glass.

FLUXES.—With reference to the fluxes that are mixed with the roasted ore, experience has shown that the earths impair the tint by diminishing its purity and lustre; and the fineness of the hue is still more damaged by soda. Lime and soda are, therefore, omitted in the mixture, and only pure potassa is employed; this is the more essential, as the matrix, which still remains attached to the ore, frequently contains lime and magnesia.

Silica is always used in the form of quartz, but is submitted to previous mechanical purification. For this purpose, the quartz is heated to redness, and then disintegrated; it is then pulverized in a stamping mill, and the meal washed, suspended in water, and the fine powder allowed to subside. The lighter earthy and ferruginous particles remain longer in suspension, and can be poured off, and by repeating the process, pure quartz-meal is at length obtained, which, when dried and heated to redness, is technically called *sand*.

The potassa is carefully prepared, calcined, and preserved from moisture. In buying this article, trials are made to verify its purity and alkalimetric strength. It is often mixed with fine sand, sulphate of magnesia, chloride of sodium, and sulphate of potassa. These impurities must be guarded against. Before employing the potassa, it is necessary to calcine it pretty strongly in a reverberatory furnace; because, when it is long in store, it attracts moisture from the air, which not only prevents its mixing well with sand and the wasted ore, but likewise would impede the fusion of the glass. It is therefore submitted for a couple of hours to a pretty strong heat, and then crushed, dry, when it is ready for use.

The mixture of the roasted ore with quartz and potassa is carefully conducted in wooden tanks, with the addition of white arsenic, which is essential on account of the iron in the ingredients; the arsenic is used in the form of powder, as it collects in the poison galleries, and with it a small portion of oxide of cobalt is recovered, which is mechanically carried over by the draught. The depth of color in the product, the proportions of sand and potassa remaining the same, naturally depends upon the amount of oxide of cobalt in the wasted ore, or upon the quantity or quality of the schlich employed in the mixture. If the roasted ore contains much lime or alumina, these will enter into the composition of the glass, and degrade its pure tint. The coloring powers of the ore will therefore depend, not only upon the amount of oxide of cobalt which it contains, but also upon the nature of the substances associated with it. In the arts, however, a great variety of tints are in constant demand. The difficulty of obtaining a uniform and constant blue will be evident from these facts, as it must entirely depend upon the nature of the ingredients; and these are subject to change in every consecutive ustulation. As a constant quantity of potassa is always employed in the smalt works, proportionate to the sum of the other constituents of the mixture—one-third of the ore and sand together—the only question that remains to be settled is the relative proportion of ore and quartz. Two processes of testing are resorted to for establishing this point; the first informs the workman how long the roasting must be continued in order to produce the deepest blue with the smallest quantity of mineral, that is, until the ore has acquired the most intense coloring power; the second instructs him as to the quantity of sand that must be mixed with it in order to produce a certain tint. Both tests are mere repetitions of the manufacturing process on the small scale. A series of definite tints, generally three, can thus be kept constantly on hand, and from these any required modifications can be produced, by altering the relative quantities of the ingredients. A complete set of all the gradations of color producible by the constituents is requisite for this purpose, and also a series of specimens of all the tints of color required in commerce. As the desired hue can only be produced by the most accurate attention to the relative weights of the ingredients, the latter are never mixed by measure, but always by weight in the dry state. The same degree of accuracy is not necessary in adding the arsenic, as an excess in this case easily volatilizes; it is therefore added in variable quantities, up to the same amount as the ore.—*Knapp.*

DUMAS states that the mixture destined to form the cobalt glass is made according to very different proportions, varying in each factory with the nature of the mineral employed, and with the kind of the smalt required.

In glass of the shade O E G and F O E G, it is composed as follows:—

Cwt.	
2·5	ordinary roasted ore, or schlich.
2·0	roasted mixture of ore, and cobaltiferous quartz.
20·0	sand.
3·5	eschel—the faintly colored glass produced by washing the smalt.
10·0	potassa.
38·0	

Smalt marked M E, M C, and F C, is made with—

Cwt.	
2	best roasted ore.
5	sand.
2	eschel.
4	potassa.
13	

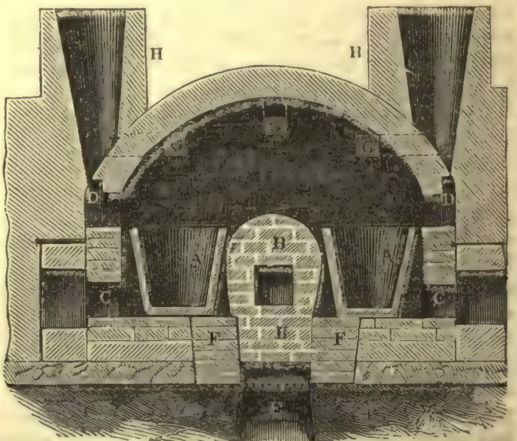
The mixture of these matters is performed in a pretty long and wide wooden trough, two feet in depth: first a layer of sand, then of schlich, and lastly one of potassa is introduced; the whole is then well mixed by means of a shovel, when it is in a fit state to be submitted to the fusion or melting process. It is customary to prepare, at one time, enough to supply the pots for a week.

FUSION.—Before describing the melting of the cobalt glass, and the furnace employed for this purpose, it will be well to say a few words on the fabrication of the crucibles or pots used in the operation. They must neither crack nor vitrify by the high temperature to which they are subjected. This end is attained by using for the purpose a refractory clay, containing no lime, and mixed with a suitable portion of dressed clay or cement.

The mixture for making the pots is composed of two parts of crude clay and one part of cement. The whole is placed in a trough, mixed with a little water, and kneaded, so as to form a perfectly homogeneous paste, thick enough to be moulded. The pot is first dried in the air, and then it is thoroughly deprived of moisture by heating it *gradually* to redness, in a furnace like a baker's oven, with a vault overhead, and adapted to contain six crucibles at a time. When the clay for the pots is made too damp, they have not sufficient compactness, and crack on drying. If they have not been thoroughly exsiccated in the air before introducing them into the baking furnace, they also split and are useless. The manner in which the pots are moulded has much influence on their durability; the best process consists in beating the clay round a circular core, enclosed in a hollow cylinder, separated from the core by a distance equal to that intended to be given to the crucible; the clay is heaped up gradually in small portions, and in the most uniform manner. The pots are a little conical, the larger circumference being at the upper part. They are eighteen inches in diameter at top, fourteen at bottom, and have a thickness of two inches. When they have been sufficiently exposed to the air, they are introduced into the furnace, and left there five to six days, during which the temperature is gradually raised to whiteness. Each pot is capable of holding about eighty-four pounds of the assay, and generally lasts seven or eight months.

The furnace in which the fusion is performed is similar to an ordinary glass-oven; the separation of the speiss is the only essential difference in the process, and this gives rise to certain modifications in the construction of the furnaces, which are either circular, as at Schneeberg in Tuscany, and Querbach in Silesia; or sometimes rectangular, as at Schwarzenfels in Hesse, *et cetera.* They are adapted either for coal or wood. This will be more readily understood by reference to Fig. 315.

B is one of the openings for the insertion of the pots, and after this has been effected, is walled up; the pots, A A, are pierced at the side with an orifice—speiss-hole—for the withdrawal of the speiss which is over against the *knee-hole,* C. Through this latter the speiss and waste-glass are removed from the furnace, and the aperture is closed during the fusion. The working hole, D, is situated directly above, and serves for introducing and removing the ingredients and the glass. The flame is kindled on the grate, E, enters the furnace at F F, and passes out through the holes, G G G, which are in connection with the short chimney. Each pot, as before said, contains about eighty-four pounds of material, which is introduced by means of iron ladles furnished with long handles. New pots are first filled with eschel, so as to coat the interior with a glaze. In the course of eight



hours the mixture enters into fusion, the workman occasionally stirring it up with a red-hot iron to break up the crust which forms on the surface. It is only when the molten mass is at a white heat, that a chemical combination of the materials is effected; at this point the stirring must cease, and the heat be sustained, in order to aid the segregation or settling of the speiss.

Every time that the pots are recharged a depression of the temperature occurs, and it usually takes from an hour to an hour and a half to bring them back to whiteness. The furnace is said to work well if the pots glow, and the flame comes out briskly to the openings of the vault.

When the glass adheres to the workman's rod, and admits of being drawn into threads—in short, when it is homogeneous, it is ready for the next operation, which consists in ladling it out into a vessel full of water, kept cool by being repeatedly stirred. The vitrified mass falling in a molten state into water, becomes granular and easy to pulverize. If the potassa salt employed is pure, the scum, which is known as *glass-gall* or *sandiver*—impure sulphate of potassa—is not formed, but there is usually a portion to be skimmed off. When the cobalt contains nickel, an arsenide of this metal is produced, united with different metallic substances, which are deposited in the crucibles under the form of globules or masses, more or less considerable. A part of these remain even in suspension, so that in the Schneeberg works, when a pot is half emptied, they always expect to meet with globules of this alloy of cobalt, nickel, iron, arsenic, bismuth, and sometimes silver, which is known under the name of *speiss*. Every time that the workman draws off the blue glass, he allows this matter to deposit in his ladle, and before throwing the glass into water, he makes the speiss fall into an iron basin provided for its reception. At Schwarzenfels, the speiss is removed by a manipulation which appears more certain. There, each of the eight pots which the oven contains presents in its lower part a small orifice, which is stopped up during the melting, but is opened when it is nearly completed. It is by this that the workman allows the speiss which is collected in the bottom of every pot to flow out. Then he draws off the blue glass. This, running out quite red hot into the basin of cold water, explodes, breaks into pieces, and becomes easier to pulverize. When a pot is empty, it is not refilled immediately; the glass is first drawn from all the other pots; because, while charging with new material, the furnace would cool, and the temperature being too depressed, it would not be possible to empty the last pot completely.

When they are all empty, a recharging takes place, and the melting is continued in the manner described. The cold glass is withdrawn from the water, then put to drain in a wooden trough, and carried to the store.

During the melting, there forms what is called *verre de sole*, or waste glass; it proceeds from a part of the contents running over the pots, or spilling by the breaking of the vessel. This glass collects on the sole of the furnace, runs out by the opening for the flame, and mixes with the ashes; it is gathered up, crushed, washed, and serves for an addition to the charges in greater or less quantity.

GRINDING AND WASHING.—The reduction of the glass into the state of powder is effected by two granite stones, working under water in a wooden trough, which receives the smalt, previously finely stamped or broken into fragments between rollers. After grinding some hours, an orifice in the wooden case which envelopes the millstones is opened; then the ground material, which is mixed up with water, escapes into large troughs arranged to receive it. Soon the purest smalt, which is the heaviest, as it is the richest in cobalt, forms a deposit in the recipient: some minutes suffice in summer for the first quality to precipitate; in winter it is observed that the time required is longer, on account of the greater density of the water at that season.

A part only of this first quality, which is called *sanding* or strewing-blue—*streublau*—as it is used for the floors, is delivered to the market in this state; the remainder is submitted to a new grinding with the blue glass, to which it is added in small portions.

Before taking this strewing-blue from the vessels, the water in which the finer particles of azure remain suspended is withdrawn. This liquid is conveyed into a second series of troughs, then left to repose for a period, which varies from three quarters of an hour to an hour and a half, according as it is desired to obtain a finer or coarser quality of azure. That which deposits in this second series of troughs is generally called *farbe*, the German for color.

When the precipitation of the color is judged to be finished, the liquid which occupies the upper part of the troughs is conveyed into a further series of cisterns, where, in the course of an indefinite period, the deposition of the finest particles of blue glass is concluded. The result is a great number of kinds of common azure, which are designated *blue sand*, *eschel*, *vat* or *trough eschel*. *Sumpfeschel*, a substance slightly colored, and in a very fine state, remains last in suspension in the washing waters; it is an alkaline silicate, containing a very small quantity of cobalt, and easily separates from the azure on account of its low gravity. This kind is returned to the pots and again melted.

The different sorts of azure or eschel being obtained, each of them is submitted separately to a further washing in troughs, into which a liberal supply of fresh water is introduced. During this operation the workman agitates the matter with an oar, then leaves it to settle; afterwards, by means of a hair-sieve with close meshes, he frees the liquid from the impurities which float upon it. This again is made to flow, with precaution, into another trough, to proceed, in the same manner, to a new affusion. Different products are thus obtained from the same smalt, either in the state of *farbe* or of *blue sand*.

This general description will be concluded with a special example. Let it be supposed that it is intended to manufacture the shade O C:—The ground smalt is first reduced with water, and after settling forty-five minutes, the superstratum holding the colored particles in suspension is drawn off, and poured into another trough; when the whole of the liquid has thus been removed, there remains at the bottom of the vessel what is named *le gros bleu*, or dark blue, which consists, as has been stated, of a blue glass, not in so minute a state of division as that which floats in the water. The latter is, as stated above, poured into a second vessel, called the *color trough;* it is left here to settle, longer than on the first occasion, in order to separate the colored parts which form the azure from the almost colorless particles which compose the *trough eschel*, and which would alter the shade. The liquid is thus left to itself for thirty-six hours; the water then appears slightly tinged. It is made to flow from the trough into a basin, where it is left to settle till it is colorless. Then it is thrown out, and the deposit or sediment is the *eschel de cuve*—trough eschel—which is dried and added to the melting mixtures.

The matter deposited at the bottom of the color trough is the azure, which now only requires to be subjected to washing to arrive at the last degree of purity. It is then removed from the vat, to the bottom of which it adheres strongly; is broken to pieces on the breaking-benches with mallets or wooden rollers, and afterwards submitted to several washings by decantation. About three hundredweight of material are put into the washing trough, the necessary quantity of pure water is added, and the whole is agitated with a wooden spatula till the azure is in complete suspension. The impurities which float above are removed by means of a fine sieve; they consist of a little glass-gall, which is formed during the melting of the glass, and which is of a less density than the azure. It is left to settle for twenty-two to twenty-four hours; at this stage the water is still a little colored by eschel; it is made to pass into the basin destined to receive it; then the deposit is removed and is broken, as on the first occasion. It is put back into the trough with a fresh quantity of water, agitated, left to itself for eighteen to twenty hours, and then decanted. The operation is repeated a third time, and then it is only left to settle sixteen to seventeen hours. Lastly, the liquid is poured off, and the washing is finished.

For all the shades of smalt the same mode of procedure is observed, except that the duration of the deposition varies according to the tint which it is proposed to produce.

These precipitates are removed from the different vessels which contain them, and submitted to desiccation on tablets arranged for this purpose, either in close chambers heated by a stove, or better in drying-rooms exposed to the air.

When the products are properly dried, it is still necessary to crush the compact masses which they present in this state, and to sift the powders thus obtained. For the first object, cylindrical rollers and racks moved by water are often used; sometimes ordinary mills, and occasionally two planks, which are made to slide upon each other, are employed. As regards the last sifting, it is usually performed on movable riddles, which are enclosed in cases; sometimes for this purpose a mill bolter is put in requisition.

At Querbach, when the azure is drained, it is withdrawn from the trough and carried to the breaking benches, where it is pulverised with mallets and passed to the roller. After this it is carried to the braying machine, which is formed of two wooden cylinders, turning horizontally by means of toothed pinions; the azure is placed in a hopper, whence it falls on the cylinders, which reduce it to a very fine powder. It is then submitted to exsiccation. This operation is performed in a stove-chamber, in the centre of which is a furnace. The flame and smoke, on proceeding from the fire, enter the chimney, after passing by a series of channels or passages, covered with brick in such a manner as to form a perfectly connected area; this is terminated by brick ledges four inches in height. The stove-chamber is furnished in its circumference with staged shelves, intended to receive the azure, and the temperature is kept at 105° to 112° Fahr. The moist azure is placed on the shelves, and its desiccation is completed on the area of the furnace. A layer of it is formed from two to three inches in thickness, which is turned from time to time with a rake. When the azure is judged to be sufficiently dry, it is again submitted to the braying machine, where it is triturated. One ton and a half may be dried at one time on the furnace.

The anhydrous azure is finally submitted to a last manipulation. It is carried into a chamber containing close cases, and bearing the number or symbol of each shade. In the middle is another tightly-closed case, in the interior of which a hair-sieve, placed under a hopper, is suspended on an axis. The smalt is poured into the hopper and falls upon the sieve, which the workman shakes, by giving to the shaft an alternating backward and forward movement.

The sifted smalt is put into packages, then closed up in small fir casks, containing half a hundredweight. Before being packed, it is mixed with a little water to prevent loss of the dusty substance. Each cask is afterwards marked, to show its particular shade of blue.

It is estimated that in this long series of minute operations, for one hundred parts of cobalt glass employed, ninety-five parts of matter are obtained, comprising therein the refuse of the affusions and the trough eschel, which are again used in the formation of the smalt. As regards the product for the market, it is agreed that five tons of glass yield about three tons of azure, or dark blue.

USES.—Smalt has been employed in fresco-painting, and in the making of porcelain, pottery, stained glass, encaustic tiles, *et cetera*. The paper manufacturer who fabricates animal-sized papers for account-books, deeds, bonds, *et cetera*, uses this compound to cover the yellow tinge of his ware. BERZELIUS stated that the silicic acid contained in writing-paper colored by smalt, blunted the nibs of pens. This article was at one time in request for the manufacture of bank-notes. Paper tinted by smalt affords, when calcined, an ash having an azure hue, and often eliminates the peculiar alliaceous smell due to the arsenious acid present in the imbuing material. There is some difficulty in keeping the smalt uniformly suspended in the press; hence one side of the sheet is generally of a darker shade than the other. This defect led to the use of artificial ultramarine as a substitute in all papers of an evanescent value.

The celebrated ceruleans of Sèvres porcelain are produced from cobalt dissolved in acids and precipitated.

A preparation of this kind is only attacked by agents which destroy glass, and these are so few in number, that smalt exceeds most pigments in chemical indestructibility. It is applicable to all those purposes where a cheap durable blue is required. Painters employ it, and it is used by the bleachers for finishing off cambrics, lawns, linens, and very fine cottons; by washerwomen for domestic purposes; and by starch makers. Its good quality is dependent upon the purity and uniformity of its hue; the former can only be secured in the smalt works when the mineral is sufficiently pure, and it is frequently impossible to produce the greatest depth of tint in consequence of the poverty of the ore.

Good smalt may be used for painting and coloring glass, but is not so appropriate for fine work as fluxes prepared with pure oxide of cobalt; whilst for less delicate purposes, for the paintings of earthenware, *et cetera*, the simple mixture of ingredients will obviously produce the same effect as the prepared pigment, both having subsequently to be either adusted or fused. Indeed, large quantities of roasted ore, mixed with the necessary addition of flint powder, are sent into the market under the name of zaffre or safflor. The names *smalt*, *smaltum*, derived from *schmeltz; eschel* from *ashe*—on account of the addition of an alkaline ash—and *zaffre*, a corruption from sapphire, on account of the blue color, were no doubt originally synonymous, until they were used at a later period to distinguish different products of the same process of manufacture. KUNKEL used the word smalt as a general term for any kind of glass flux, that is, white glass intended for coloring—strass. The proportion of the ingredients in the zaffre sold must be so arranged, that they shall yield, by fusion with the proper quantity of purified potassa, the exact tint ascribed to them by the manufacturer. This is ascertained by the same process of comparative testing as has been described in the case of smalts.

IMPROVED PROCESSES.—This manufacture has been lately improved in Sweden by the adoption of the annexed process:—

The cobalt ore is first roasted till the greater part of the arsenic is driven off. The residuary impure black oxide is mixed with as much sulphuric acid—concentrated—as will make it into a paste, which is exposed at first to a moderate, then to a cherry-red ignition for an hour. The sulphate thus obtained is reduced to powder, and dissolved in water. Carbonate of potassa is gradually added to the solution, in order to separate the remaining portion of oxide of iron, the quantity of which depends upon the previous degree of calcination. If it be not sufficiently oxidized, the iron is difficult of removal. When, from the color of the precipitate, it is found that the potassa separates merely carbonate of cobalt, it is allowed to settle; the supernatant liquor is decanted and precipitated, by means of a solution of silicate of potassa, prepared as follows:—Ten parts of potassa are carefully mixed with fifteen parts of finely-ground flint or sand and one part of pounded charcoal. This mixture is melted in a crucible of brick-clay, and steady ignition is required during five or six hours. The fused mass, when pulverized, may be easily dissolved in boiling water by adding a little at a time. The filtered solution is colorless, and keeps well in the air, if it contains one part of glass for five or six of water. The silicate of cobalt, which precipitates upon mixing the two solutions, is the preparation most suitable for painting upon porcelain and for the manufacture of blue glass.

The following is another method for making this fine blue pigment:—

The ore of cobalt is to be reduced to very fine powder, and then roasted with much care. One part, by weight, is next to be introduced, in successive small portions, into an iron vessel, in which three parts of bisulphate of potassa have been previously fused at a moderate temperature. The mixture, at first fluid, soon becomes thick and firm, when the fire is to be increased until the mass is perfectly molten and all white vapors have ceased. It is then to be taken out of the crucible with an iron ladle, the latter is to be recharged with bisulphate of potassa, and the operation continued as before until the vessel is useless. The fused mass contains sulphates of cobalt and potassa, and arseniate of iron, with a little cobalt. It is to be pulverized, and boiled in an iron vessel with water as long as the powder continues rough to the touch. The white, or yellowish-white residue, may be removed from the solution either by deposition or filtration. Carbonate of potassa, free from silica, is then to be added, and the carbonate of cobalt thrown down is to be separated and well affused, if possible, with warm water; the same liquid may be used to wash other portions of the fused mass. The filtrate which first passes is a saturated solution of sulphate of potassa; being evaporated to dryness in an iron vessel, it may be reconverted into bisulphate by fusing it with one half its weight of sulphuric acid. This salt is then as useful as at first.

The oxide of cobalt thus obtained contains no nickel; so little oxide of iron is present, that infusion of galls does not show its presence; it may contain a little copper, if that metal exists in the ore; but it is easily separated by the known methods. Sometimes sulphide of hydrogen will produce a yellow-brown precipitate in the solution. This, however, contains no arsenic, but is either sulphide of antimony or bismuth, or a mixture of both.

It has been found advantageous to add to the fused mass sulphate of iron, calcined to redness, and one-tenth of nitrate of soda when the residue is arseniate of cobalt. There is then no occasion to act upon the resulting compound a second time for the cobalt it contains.

The process is founded on the circumstance that the sulphate of cobalt is not decomposed by a red heat, and that the arseniates of iron and cobalt are insoluble in all neutral liquids. It is quite evident that, to obtain a perfect result, the excess of acid in the bisulphate of potassa must be completely driven off by the heat applied.

The largest manufacturers of smalt in the United Kingdom, are Messrs. RAWLINS and SON of Liverpool, and Mr. MEIGH of Staffordshire. The price of this article varies from sixpence to two shillings and threepence per pound.

Henry Hussey Vivian took out a patent in 1851 for improvements in obtaining nickel and cobalt. He found that these, in quantities of considerable value, were contained in copper ores, either the produce of foreign countries or of England, and that, in the treatment of such for copper, these metals have been wasted; a portion of them remaining in the refined copper and deteriorating its quality, another being thrown away in the slags, and a third being contained in a product called white or hard metal, commonly used in the manufacture of nails, or sold at an inferior price. The object the patentee had in view was the separation of the above-named valuable metals, and obtaining them in a marketable form.

The invention consists in the separation of nickel and cobalt, or either of them, in the form of arsenides, from ores, slags, or regulus, and other combinations or alloys of copper, which is effected by means of the affinity of nickel and cobalt for arsenic, and of copper for sulphur. The means by which this is carried into effect will now be described; but, for convenience, the process will be separated into two divisions.

By the first process, included in the first division, is obtained an impure arsenical compound, containing nickel and cobalt, separated from the mass of matter with which they were at first associated. By the second, Mr. **Vivian** obtained the arsenides of nickel and cobalt in a marketable state.

As to the first division, although in all cases a like result is arrived at, yet the different characters of the substances which contain nickel and cobalt, render it necessary that various means should be used, according to the material operated upon, and in order to make this more clear, the minerals, *et cetera*, will be divided into four classes.

Firstly, Ores, slags, and compounds containing copper and other metals, the whole or chief part of which are in an oxidized state. These he mixes with arsenical pyrites, containing sufficient arsenic to absorb the whole, or nearly the whole, of the nickel and cobalt, together with a portion of copper contained in the material, and at the same time adds, in the form hereafter mentioned, sufficient sulphur to take up the remainder of the copper, together with coal or carbonaceous matter, for the more complete reduction of the oxides. This mixture is then melted, and the melted mass tapped into a bed. After skimming off the slag, the arsenical portion sinks to the bottom of the pigs, and is readily separated, when cool, from the superincumbent regulus of copper. The arsenical combination thus obtained will be found to contain nearly the whole of the nickel and cobalt; and it is then dealt with by the second step. It may happen that the whole of the arsenical combination has not separated itself from the regulus of copper in the first melting: in this case, the regulus is once or twice re-melted, and tapped in the same way, until the arsenical deposit is exhausted.

In the above process, arsenical pyrites is prepared as a suitable substance for introducing arsenic. Sulphur may be given by the addition of iron pyrites or raw ore furnace metal, either of which have been found to answer well.

Secondly, Copper ore and regulus containing small quantities of nickel and cobalt, and in which the metals are not in an oxidized state. These are smelted in the usual manner, until a regulus, containing about seventy per cent. of copper, commonly known as *white metal*, is obtained; this is then roasted in the same way as would be done for the purpose of producing a metallic bottom. On the completion of the first portion of the ustulation, when the plug holes are to be closed, and prior to melting for tapping, arsenical pyrites is added, three to five hundredweight of which, to thirty hundredweight of regulus, has been found to produce the desired effect; on tapping the furnace into the ordinary sand-bed, and lifting the pigs when cool, a metallic bottom will be found under the first three or four pigs of regulus, in which the largest portion of the nickel and cobalt, contained in the regulus originally treated, will be concentrated.

This metallic bottom is a low arsenical compound, easily broken, and presenting a greyish fracture, approaching that of cast-iron, which is afterwards treated according to the second process. For the above, even without the special addition of arsenic, from the natural presence of that substance in most copper ores containing nickel and cobalt, a certain concentration takes place in any metallic bottoms formed by roasting, but to an inconsiderable extent, unless ores should be purposely so mixed as to cause the regulus to be highly arsenical; should such occur, the bottoms will be treated in the same way as the fourth class.

Thirdly, Copper ores or regulus, holding large quantities of nickel and cobalt, and in which the metals are not in an oxidized state. In these ores there will generally be found a large portion of arsenic. Such ore is melted in the usual manner; but instead of allowing the metallic products to run into water, in order to granulate for subsequent calcination, they are cast into pigs. It will then be found, that at the bottom of one or more of the first pigs of regulus a product of a different character from the regulus will have been deposited, from its greater specific gravity, which when broken will have a light white fracture, and is an arsenical combination of copper, nickel, cobalt, and other matters, being that product which it is desirable to obtain by the first step, and which is subsequently treated specially for nickel and cobalt by the second method. This arsenical product will separate easily from the superincumbent copper regulus, and will be found to contain the greater portion of the nickel and cobalt orginally in the ore. Should arsenic not have been present in considerable quantity, it may be added in the form mentioned, and the same effect produced.

Fourthly, Cupreous ores. In order to separate nickel and cobalt from such alloys, the same principle is followed, namely, that of the production of the two combinations—the one a regulus of copper and other metals, with little or no nickel or cobalt—the other, an arsenical combination, containing nearly all the nickel and cobalt originally present; which is effected either by adding the alloy desired to be treated in either of the above-described processes, placing it at the top of the charge of materials when they are first put into the furnace, or by first melting such metallic compound, in order to allow it to run into water to granulate, and then mixing it with substances containing sulphur and arsenic, and proceeding precisely as in the case of materials classed number one in this description, but without the admixture of coal.

It now remains to speak of the second step, or second general division, of this invention, namely, the obtaining the arsenide of nickel and cobalt in a marketable form.

By the processes described, the greater portion of the nickel and cobalt has been separated from the mass with which they were mixed, and there has been produced an arsenical product containing them, in the proportion varying from one to twelve per cent., according to the original contents of the same in the materials treated; the remaining constituent parts of this arsenical product are generally from fifteen to fifty per cent. of copper, together with iron, antimony, and other matters, depending entirely on the contents of the materials from which it has been produced; and the object of the second step is the separation of such copper, iron, and other extraneous matters contained in the above-mentioned arsenical product, and the consequent concentration of the nickel and cobalt.

This point is arrived at as follows:—The impure arsenical compound is to be pulverized or granulated, and then calcined in the ordinary manner. After calcination, the material is melted, with the view of converting the copper, zinc, and other matters into a regulus, the oxide of iron into a slag, and the nickel and cobalt into arsenides; and for these purposes, sulphur, silica, and arsenic are added, sufficient of the latter to absorb the whole of the nickel and cobalt, together with portions of the other metals, rather than by want of arsenic to allow nickel and cobalt to be present in the copper regulus. For the purpose of adding sulphur, sulphate of baryta has been found very suitable, inasmuch as it contains no iron or other impurity, which might enter into combination with the arsenide of nickel; and in the event of using it, or other sulphate, coal or other carbonaceous matter must be added. In order to introduce arsenic, preference is given to arsenical pyrites, which at the same time parts with its sulphur, and assists in forming a regulus of copper. The silica is added in the form of common sand. For these purposes, twelve parts of silica, ten of arsenical pyrites, eight of baryta, to seventy parts of arsenical product, and one part of coal to four of sulphate of baryta, have been used.

The products of this melting are:—

Firstly, Regulus of copper, antimony, zinc, iron, lead, silver, and other such metals as may have been present; as also a certain small portion of nickel and cobalt which may not have separated from it, being, as it were, suspended in it.

Secondly, Arsenides of nickel and cobalt, together with portions of the other metals, which, as before stated, it is preferable to obtain in this arsenical product, rather than incur the risk of any portion of nickel and cobalt remaining in the regulus for want of arsenic.

Thirdly, Slag containing chiefly the iron originally present in the material. The slag is skimmed off in the usual manner; and the regulus and arsenical product are tapped, and these separate in cooling by their respective specific gravities. This regulus is melted slowly, and tapped to a bed, where an arsenical product, containing nickel and cobalt, will again be found under the first few pigs, for the first two or three meltings, after which it will be generally free from these; and in case it should not be quite pure, a semi-arsenical bottom may be taken from it, as in the case of ordinary copper regulus before described, which will free it, or nearly so, from the last portions of nickel and cobalt.

The arsenical product obtained by this second step will be found to be free from the greatest portion of its impurities, and will contain a largely increased per centage of nickel and cobalt; but in case it should not be sufficiently pure to be marketable, which will commonly be the case, it is again pulverized or granulated, calcined, melted, and treated precisely in the same manner, until an arsenide of nickel and cobalt of the required purity is obtained.

QUANTITATIVE ESTIMATION.—Cobalt is determined quantitatively in various ways. The following is the method generally followed when no other metal is present. The acid solution is boiled with an excess of *aqua potassæ;* the precipitate, which at first is bluish, becomes, after long ebullition, of a dirty-red color; if ammoniacal compounds are present they must be decomposed, and the volatile alkali expelled by long-continued boiling with a great excess of the fixed alkali; the precipitated hydrate, after being collected on a filter, requires a liberal aspersion with hot water, when it is dried, ignited, and weighed. In this state its color is black and its constitution variable, according to the degree of heat employed.

The Editor, who has had great practice in the analyses of cobalt compounds, obtained most satisfactory results by the above method, sufficiently accurate for all manufacturing purposes. To reduce a known weight of the oxide to the metallic state, and then weigh, is not only troublesome, but, with inexpert hands, dangerous; hydrogen gas having to be passed over the glowing assay. Instead of calculating from the protoxide, it will be safer in all cases to assume that $Co_6\,O_7$ is obtained, when the results will be found perfectly correct. The following will be a guide to the analyst.

Suppose that two grammes of the substance to be analysed yielded half a gramme of oxide of cobalt—$Co_6\,O_7$—how much metal, Co, would the half gramme contain?

The atomic weight of cobalt is 29·50, and oxygen 8·00, consequently $Co_6\,O_7$ would be represented by 225.

$$\text{As—}\ \overset{Co_6\,O_7}{225{\cdot}00} : \overset{\mathrm{Go}}{177{\cdot}00} :: \overset{Co_6\,O_7}{0{\cdot}50} : 0{\cdot}393.$$

If the per centage be required, it is calculated as follows:—

$$2{\cdot}00 : 0{\cdot}393 :: 100 : 19{\cdot}65 \text{ per cent.}$$

When the cobalt is not alone, but associated with other metals of different groups, the annexed procedure, although not very accurate, will in many cases suffice:—

A stream of sulphide of hydrogen is to be passed through the acid solution, which will precipitate all the metals except cobalt, nickel, iron, and zinc. The whole, when it *strongly smells of the gas*, is to be heated and filtered; to the filtrate, ammonia and sulphide of ammonium are to be added, to throw down as sulphides the above enumerated metals. Filter, wash well, and treat the residue carefully with *weak hydrochloric acid*, which will immediately dissolve the iron or zinc, leaving the sulphides of nickel and cobalt almost intact. Filter, wash, and dissolve in *aqua regia*, precipitate by potassa, and affuse the oxides well with hot water; then dissolve them in pure cyanide of potassium, and boil with an excess of freshly-precipitated oxide of mercury. The whole of the nickel deposits in combination with the mercury; filter, and saturate with acetic acid; boil; next add sulphate of copper, and then repeat the ebullition. The precipitate has the following composition:—$Cu_3\ Co_2\ Cy_6$. Collect, and ignite it to destroy the cyanogen; dissolve in *aqua regia*, and separate the copper by sulphide of hydrogen. This must be re-dissolved, and the oxide of copper precipitated from its boiling solution by potassa. From the copper the cobalt is calculated, three equivalents of the former being equal to two of the latter.

A very accurate method for determining cobalt in compounds containing arsenic, copper, *et cetera*, in the first group, and only cobalt and iron, with traces of nickel, in the second, which would not interfere with the analysis—and this is *nearly always the composition of the ores submitted to the chemist*—is to pass sulphide of hydrogen through the acid solution, and filter; and to the filtrate add ammonia and sulphide of ammonium, again filtering, then dissolving the sulphides of cobalt and iron in *aqua regia*, and boiling for some time, to get rid of sulphide of hydrogen; then add sufficient ammonia—great care and skill are to be exercised at this stage, or else a portion of the oxide of cobalt will fall—so as to precipitate a few flakes of sesquioxide of iron; succinate or benzoate of ammonia is then added, and the precipitated sesquisuccinate of iron filtered off; add to the filtrate sulphide of ammonium in excess; filter and wash well, then dissolve in nitrohydrochloric acid, precipitate with potassa, and proceed as in the first analysis. The results are most accurate; and the method will answer for nearly all the compounds of cobalt that are used in the smalt works.

The analysis of smalt is performed in a similar manner to that of glass; but as it will be quite unnecessary here to go into full details for the separation of each substance, the Editor will only give a process by which the amount of silicic acid and oxide of cobalt may be determined:—

Take one hundred grains of the smalt, previously reduced into very fine powder, and mix it carefully with about four hundred grains of dry carbonate of soda, also thoroughly triturated; put the mixture into a platinum crucible or capsule, and maintain it in a perfectly molten state for about half an hour. When cold, place the crucible containing the fused mass in a wide porcelain capsule, and carefully pour an excess of dilute hydrochloric acid upon it, whereupon all the oxides, earths, and alkali, as well as the silica, will be dissolved. Wash the crucible clean, and carefully evaporate the whole of the liquor, with whatever residuum it may contain, to dryness, and then increase the heat to about 500 or 600 Fahr., which will render the silica insoluble. The resulting mass must now be treated with acidified water, which redissolves the oxides, but leaves the silica intact; this is to be collected on a filter, washed, dried, ignited, and weighed.

The liquor filtered from the silica is then treated with an excess of potassa, which precipitates the oxides of cobalt and iron—the alumina is retained in solution; filter, and wash well, then dissolve in *aqua regia*, precipitate the iron, as above, with succinate of ammonia, filter, *et cetera*. The oxide of cobalt obtained ought not to be *under twelve per cent.*

Should the speiss, or other cobaltiferous substance to be analyzed, contain nickel, a very excellent process for its separation is the annexed:—After making a solution of the substance, and removing the bismuth, copper, arsenic, iron, *et cetera*, in the usual way, dissolve in water one-half the weight of the speiss taken, of bleaching powder; plentifully dilute this solution, adding to it very weak sulphuric acid, slightly in excess, it being requisite that no free lime nor undecomposed chloride should remain, as either would affect the nickel salt; then this solution is poured into the cobalt and nickel menstruum—also much diluted—a thin cream of carbonate of lime added in excess, and the mixture digested for twenty-four hours at the least, or for days if it be inconvenient to proceed with the analysis, when the decomposition of the cobalt salt is complete; and the oxide of this metal, mixed with the excess of carbonate of lime, may be entirely separated by filtration from the nickel which remains in solution.

The manufacturer of the oxide of cobalt may derive some useful information from the above in the management of his process.

ADULTERATION.—The oxide of cobalt and smalt are not compounds that are often sophisticated to any great extent; still there are cases where the former, instead of having ninety-seven or ninety-eight per cent. of oxide of cobalt—if it contains more than two per cent. of impurities, it is perfectly unsaleable in the potteries, except for certain very limited purposes—has been found to yield *only thirty per cent.* If a portion of oxide of cobalt be heated with hydrochloric acid, it should yield a solution—without any residue—of a magnificent blue color, similar to that of copper in ammonia; if it has the slightest tinge of green, iron or nickel, or both of them are present. When this solution is diluted with water, the tint should immediately change to a pure, bright, and deep rose; and caustic potassa should precipitate the cobalt as hydrate, in fine blue flakes, without effervescence, and these should be converted, by ignition at a low red heat, into a fine black powder. If oxide of cobalt fails in one of these characteristics, it may confidently be declared impure.

Its several adulterations or contaminations are generally oxide of nickel, sesquioxide of iron, copper, lead, zinc, arsenic, antimony, bismuth, alumina, silica, magnesia, and lime. The presence of these may be detected as follows:—Treat two or three grammes of the powder with hydrochloric acid, which will produce a brisk evolution of chlorine. Should the whole not have dissolved, the sediment is generally silica and sesquioxide of iron. Filter, and pass a stream of sulphide of hydrogen through the filtrate. If this produces at once a black coloration or precipitate, it is owing to the presence of copper, bismuth, or lead merely; the precipitate, however, is often mixed with brown and yellow particles, more or less abundant, of antimony or arsenic. If no lead or copper be present, and the precipitate produced is yellow, it is sulphide of arsenic; if orange-red, sulphide of antimony. When *black*, sulphides of copper, lead, bismuth, arsenic, and antimony may be present; if so, they are each detected as below:—

The arsenic will be recognised in the oxide of cobalt, before being dissolved, by heating a portion of it on charcoal before the blowpipe flame, when the unmistakable alliaceous smell will be perceived, an infallible proof of the presence of this metal. The antimony can be detected by washing the sulphide of hydrogen precipitate with sulphide of ammonium—sulphides of antimony and arsenic dissolving in this reagent—and filtering; should the filtrate give an orange-red coloration or precipitate, it proves the presence of antimony. After treating with sulphide of ammonium, the residue is to be thoroughly affused with hot distilled water, then dissolved in hot weak nitric acid, and filtered. To the filtrate add dilute sulphuric acid, and boil; a white precipitate proves that lead is present; filter, and into the percolating liquid pour an excess of hydrochloric acid, and shake well; a cloudiness or curdy deposit shows silver; filter, and supersaturate the filtrate with ammonia, which will throw down teroxide of bismuth, should this have been among the impurities; again filter; if the liquid passing through is colored, or has a bluish tinge, copper is indicated. To determine the quantities of each of these metals would be an endless task; therefore, the best way to ascertain the extent of the degradation of the sample, is to take a known weight of the oxide, and to precipitate its filtered acid solution with sulphide of hydrogen; filter; to the filtrate, add ammonia and sulphide of ammonium in excess; re-filter; wash the precipitate well, dissolve in *aqua regia*, and proceed with it as at page 492, separating the iron by succinate of ammonia, *et cetera*. From the per centage weight of *oxide of cobalt* obtained, the quantity of impurities may at once be known.

Smalt is sometimes adulterated with chalk; this fraud, however, may be immediately detected by pouring a little hydrochloric acid upon it, which, in that case, will produce an effervescence.

The composition of a good sample of smalt ought to give about the following:—

	Centesimally represented.
Protoxide of cobalt,	15·00
Oxide of iron,	4·50
Oxide of lead,	4·90
Alumina,	5·40
Potassa,	14·50
Silicic acid,	55·70
	100·00

STATISTICS.—The amount of smalt annually manufactured in England, may be stated at about one hundred and seventy tons. The quantity imported, and also that retained for home consumption, are as under:—

Year.	Imported.	Retained.
	lbs.	lbs
1847	287,623	198,206
1848	153,424	188,719
1849	205,450	218,457
1850	177,846	192,186
1851	116,751	141,153
1852	182,879	156,464
1853	—	—

The importation of zaffre during the same period is as follows:—

	cwts.		cwts.
1847,	2274	1851,	1454
1848,	1299	1852,	2021
1849,	1400	1853,	—
1850,	1682	1854,	—

The whole of the last-mentioned have been made use of in England.

COPPER.—*Cuivre*, French; *kupfer*, German; *cuprum*, Latin. This metal has been known from the remotest times. Sacred history mentions TUBALCAIN as an artificer in certain metals, including an alloy of copper, which seems to have been in early ages extensively employed in the formation of domestic and martial implements, as well as for decorative purposes. No mention has been made of copper, *per se*, being in use at the time thus indicated; only the word translated *brass* occurs; and this body, according to the revelations of modern analysts, has been found to consist of copper, tin, and very small quantities of other metals, such as iron, lead, *et cetera*. Such a mixture is called *bronze* at the present day; brass being made of copper and zinc in certain proportions. It is recorded that a celebrated mine of copper, in the peninsula of Sinai, was wrought by CHEOPS CHEFU, in the fourth dynasty. WERNER is of opinion that copper was the first of the metals discovered and extracted by man, both from the physical nature of its ores, and the facility with which it fuses. There is little doubt, however, that the ores of copper were smelted. JOB distinctly says, "copper is molten out of the stone;" and, after the metal was obtained, it was subsequently alloyed with tin to form bronze. The course adopted by the ancient metallurgists for extracting the metals is veiled in obscurity; but, as with most of the productions of antiquity, it may be presumed to have been tedious, laborious, and imperfect.

The Syrians and Phœnicians were, as appears from various records, and the quantity of bronze which they manufactured, large traders in copper; and, doubtless, during the search of the latter people for tin in Great Britain and Ireland, they found considerable quantities of the metal. This is the more probable, from the circumstance of many bronze articles being lately discovered in some of the old workings in Cornwall, attributed to that commercial people.

Copper seems to have derived its name from *Cyprus*, the island from which the Greeks first procured their supply, and which, with Rhodes, continued for a considerable period to constitute the great emporium for the metal, somewhat resembling in this respect the Cornwall and Swansea of Great Britain.

In the middle ages, roofs of houses were occasionally constructed of copper, or covered with it, and laws were usually engraved upon plates of this metal. In the alchemist's nomenclature, copper was called *Venus*, not so much on account of the beauty of its lustre, it being accounted an imperfect metal, but from the facility with which it united to, and was changed by other bodies. It is only within the last fifty years that mining operations have been prosecuted with energy; and, consequently, the copper trade from this, as well as from the many improvements in dressing and smelting ores, has acquired its present magnitude.

Native copper is found in large quantities in the mines of Cornwall and Devon in England, in those of Saxony, Hanover, Sweden, France, and Siberia, in various parts of America, and in other countries. Its forms are various, being met with crystallized in cubes and octahedra; massive capillary dendritic copper is also obtained in many mines in the above-named localities.

This metal associates itself with other bodies forming a numerous class of minerals, the principal being the following, to the names of which is appended their quantitative composition in round numbers:—

Name.	Locality.	Composition.					Analyst.
		Copper.	Sulphur.	Iron.	Arsenic.	Water.	
Subsulphide of copper,	Siberia,	78·5	18·5	2·25	—	—	Klaproth.
Purple „ „	Killarney,	61·0	23·75	14·00	Silica. 0·5	—	Phillips.
Grey „ „	Freyberg,	48·0	10·00	25·50	Arsenic. 14·	Silver. 0·5	Klaproth.
Copper pyrites,	Cornwall,	30·0	35·16	32·20	Silica. 2·64	—	Phillips.
Red oxide of copper,	Cornwall,	88·5	Oxygen. 11·5	—	—	—	Chevenix.
Black „ „		79·83	28·17	—	—	—	
Blue carbonate of copper,	Chessy,	55·00	14·00	—	Carbonic acid. 26·	Water. 5·0	
Green „ „ „	Siberia,	56·00	14·00	—	21·25	8·65	Vauquelin.
Sulphate „ „		24·00	8·00	—	Sulphuric acid. 31·57	36·30	Berzelius.
Brochantite „ „		53·	15·00	Tin, &c 3	17·43	11·91	Magnus.
Atacamite,	Peru,	57·	15·	—	Hydrochloric acid. 11·	17·0	Proust.
Euchroite,	Libethen,	39·07	8·78	—	Arsenic acid. 33·02	18·80	Turner.
Leroconite,	Cornwall,	38·20	10·80	—	14·	35·	Chevenix.
Libethenite,		51·12	12·78	—	Phosphoric acid. 28·7	7·4	Berthier.
Phosphoro-calchite,		50·	13·	—	2·20	15·	Arfwedson.

Besides the minerals enumerated, there are many others which yield copper in moderate quantities, but which it will be unnecessary to specify. A few of those tabulated are not of very frequent occurrence, but still are of value in a mineralogical point of view. Of those that are most interesting to the miner, a few additional particulars will now be given.

NATIVE COPPER occurs in mines, as before noticed, in various shapes, especially in Cornwall, Brazil, and Siberia. Masses of the metal, which weighed more than a ton, have been found in the district adjoining Lake Superior, in America. Its occurrence in the native form is accounted for, by presuming that the sulphate of copper, which would result from copper pyrites in the presence of moisture, has been exposed to an electro-chemical action, by which the metal was deposited.

Such a decomposition often takes place in the laboratory; and, in all probability, in the mine where electrical currents prevail, the copper is produced by the same agency.

SULPHIDE OF COPPER.—*Cuivre sulfuré*, French; *Kupfer glanz*, German.—This is a very valuable ore, on account of its richness in copper; but it is not so widely disseminated as other sulphur compounds of the metal. It has a greyish color, resembling iron, and is often iridescent. Some of the Cornish mines contain this mineral crystallized in hexahedral tables; but considerable quantities are found in lamellar masses. The primitive form of the crystals is a six-sided prism. When pure, sulphide of copper is very fusible, yields easily to the knife, and has a density between 5·5 and 5·8, depending on the form of the mass. It is nearly always contaminated with some portions of sulphide of iron, which render it harder and less fusible than when quite pure.

Its composition may be represented from the analysis given by Cu_2 S, and is therefore a disulphide.

PURPLE COPPER.—*Cuivre pyriteux hépatique panaché*, French; *bunt kupfererz*, German.—This mineral is more frequently encountered than the preceding, especially in Cornwall, where it is usually crystallized in cubes or octahedra, and of a reddish-brown color, occasionally exhibiting a blue, purple, and red tint. The massive ore has sometimes a red appearance. Before the blowpipe it comports itself like the sulphide, fusing and evolving sulphurous acid vapors in the oxidating flame. The crystallized variety, which is almost confined to the Dalcoath and Tin Croft mines, in the neighborhood of Redruth, afforded to VARRENTRAPP the annexed results:—

	Centesimally represented.
Copper,	58·20
Sulphur,	26·96
Iron,	14·84
	100·00

COPPER PYRITES.—*Cuivre pyriteux*, French; *kupferkies*, German.—This is the ore of copper most commonly met with; and the principal portion of the metal produced in Great Britain is obtained from it. It is found in various shapes, sometimes beautifully crystallized in cubes and octahedra; in massive, mammillated, stalactitic, and botryoidal masses. It has a marked brassy color and metallic lustre. Its specific gravity is variable, ranging between 4·1 and 4·3. The principal localities in which it is produced are Devon and Cornwall, in England; Chessy and Saintbel, near Lyons, in France; in Saxony; at Eiseleben and Strangerhausen, in Prussia; at Gosler, in the Lower Hartz; Kremnitz and Chemnitz, in Hungary; Fahlun, in Sweden; the Ural Mountains, in Russia; Island of Cuba, *et cetera.*

The formula for copper pyrites, deduced from the analysis in the table, is $Cu\,S + Fe\,S$. As brought to market, however, the ore is not always of the degree of purity indicated by the preceding equation; nearly all the Cornish product, as it is purchased, averages between six and eight per cent. of copper, the remainder being mostly iron, sulphur, and silica.

Before the blowpipe, copper pyrites fuses with the evolution of sulphurous acid into a black globule, which, from the presence of iron, becomes magnetic. With carbonate of soda on charcoal, it readily yields a metallic button. The mineral is easily soluble in nitric acid, affording a solution which, when heated with an excess of ammonia, gives a beautiful blue solution, and a precipitate of sesquioxide of iron.

GREY COPPER.—*Cuivre gris*, French; *fahlerz*, German. This ore has a steel-grey color, but varies between that tint and iron-black. It is met with occasionally crystallized in well-defined cubes and tetrahedrons, as is the case with the ore found in the St. Anstall mine, Cornwall, whence the finest specimens are obtained; but the usual state in which it is discovered in other parts of England, in Ireland, and many of the Continental mines, is in massive masses. Zinc, silver, antimony, arsenic, iron, and other metals, are found associated with this mineral. It is very brittle, and has a specific gravity of 4·6 to 5·0. Before the blowpipe, it exhibits the usual characteristics of the other sulphides of copper.

RED OXIDE OF COPPER.—Suboxide.—*Cuivre oxydulé*, French; *kupferroth*, German. One of the physical characters of this mineral is its deep blood-red, brownish, or ochreous color; it has also a subtransparent, subtranslucent, and semi-metallic appearance. It is often found crystallized in cubical, but most usually in octahedral crystals, of a fine ruby-red. Its fracture is conchoidal, and its streak reddish-brown. Its specific gravity is 5·992; and its composition, as seen in the foregoing table, is represented by the formula $Cu_2\,O$. Most of the Cornish mines contain this compound; also several of those in France, and other countries. When treated before the blowpipe, it turns black, fuses, and affords, by continuing the reducing flame, a globule of copper. In the loop of the platinum wire, it colors the outer flame green; and if moistened with hydrochloric acid, a beautiful blue flame results.

BLACK OXIDE OF COPPER.—*Cuivre oxyde noir*, French; *kupferschwartz*, German. Red oxide and botryoidal copper ore are nearly always associated with this oxide, which is found in most of the localities where the red variety is detected. Sometimes other substances, such as pyrites, iron, arsenic, and manganese, contaminate it. The ore is brittle, and soils the fingers. Before the blowpipe, it is fusible; and by reducing agents yields a metallic globule.

BLUE AND GREEN CARBONATE OF COPPER.—The blue carbonate, which is known to mineralogists by the term *azurite*, from its fine bright azure color, is found generally in mammillated concretions. It is occasionally detected in crystals derived from the rhomboid, and which are transparent, but more generally translucent; it gives a fine blue streak, has a conchoidal fracture, and a specific gravity ranging between 3·7 and 3·9.

The green carbonate is likewise known as *malachite*. It is rarely crystallized; but when so obtained, the figures are derived from the oblique prism. Its occurrence is usually in reniform masses and amorphous fragments; but it is sometimes met with in a pulverulent state, and friable, as well as in stalactitic masses. In the latter form, its structure is in fibrous layers. Both these minerals are very valuable ores of copper, on account of the large per centage of metal they afford, and the comparative facility with which they are worked. Besides being sought for by the metallurgist, the lapidary highly prizes the green carbonate, of which several ornamental articles are constructed. Sometimes tables, sideboards, and such like, are very elaborately inlaid with this mineral; and, when smoothed and polished, they have a fine effect. Many specimens of this kind of workmanship were exhibited at the World's Fair in 1851, and especially by Russian artists. The Editor considered the malachite department one of the greatest attractions at the Crystal Palace. When this mineral is sufficiently compact, it is made into brooches, bracelets, studs, *et cetera,* and cut into various articles designed for use or ornament.

The density of malachite is from 3·6 to 4·0; its composition a protocarbonate; and, according to the analysis already given, may be represented by the formula $2\,(Cu\,O,\ CO_2) + HO$. Both these minerals are found in some of the mines in Cornwall and Cumberland, as also in Ireland, France, and other parts. Before the blowpipe, both carbonates are reduced to a black globule, which, under the influence of the reducing flame, gives a button of copper.

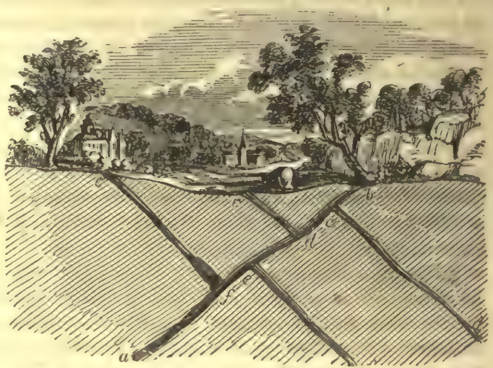
The other minerals of copper are not of very frequent occurrence; and, therefore, to the practical miner, they are comparatively of little importance, and hence will not be further dwelt upon.

Before entering, however, upon the precise methods of procedure that are followed, either in preparing the pure metal in the laboratory, or smelting on the large scale, it will be well to take a brief view of the occurrence of the ores in mines; and although by this digression an intrusion upon the borders of the province of geology cannot be avoided, still, considering that chemistry is so intimately connected with that science, the Editor feels satisfied that no excuse will be necessary.

Copper is usually discovered in fissures which intersect or intervene the same or different kinds of rocks, and which seem to have been produced by convulsions of the interior of the earth at distant ages. Much difference of opinion exists among practical miners as to the origin of the mineral contents of these fissures or veins, some maintaining that the ore has accumulated by a gradual infiltration from the adjacent rocks, through the agency of electrical currents; while others affirm that the minerals were upheaved by the eruptions in a fluid state, and deposited in the way in which they are found in mining operations. Numerous phenomena seem to justify both conclusions, yet neither can be affirmed in a general law, as many mines give ample indications which are contradictory of either the one or the other. It appears, indeed, that the true cause of the metallic depositions in strata of rocks, *et cetera*, is still a problem, the solution of which will no doubt be the future reward of diligent observation and study.

In Europe, the great repository of metallic matters is the strata of gneiss or mica-slate, very little ore being discovered in the superior layers. Some deposits well worth working are found in the transition rocks, and in the lower part of secondary ones. In America, however, this order of things does not prevail, as there the copper is discovered in the layers constituting the transition series, and also in other secondary deposits, while in the gneiss very little can be detected. The occurrence of copper in mines, as above stated, is in clefts or fissures in the gneiss or secondary and transition rocks, which are called by the general term of *lodes* or *veins*, and of which there are four species known among miners; namely, the *rake* vein, the *pipe* vein, the *flat* vein, and the *interlaced* vein. The position of the vein or lode is not parallel with the strata of rock in which it is found; it intersects it not far from a perpendicular direction, and in its course cuts through several mineral planes. It invariably happens that its form is cuneated, the wider portion being in some places found at the top, narrowing as it descends, till it finally becomes so minute as to be not worth the cost of working further; at other places the converse of this occurs, for the narrow part is found overhead, and the main body of the vein is encountered as the mine is pushed downwards. Lodes or mineral veins are not entirely composed of metallic matters, other bodies, such as quartz, spar, clay, and the like, being intermixed with the ore. Indeed, lodes entirely composed of the latter often occur, and no trace of valuable minerals can be found in them. To these the miners have given the appellation of *courses*, and they frequently cause serious annoyance and inconvenience in mining operations; for, being formations of a more recent date than the metallic bodies, they throw the latter out of their direction, and the miner has to drive through them, and to continue his search for the valuable ores during a considerable time and at a great cost. A single course, although it interrupts the lode, does not offer so great a difficulty as when several of them traverse the strata; because, in the first instance, miners now, from repeated observations, have learned sufficient to serve them as data where to meet the lode again; but in the second, the frequency of the shifting disheartens the speculator as well as the miner, and, after long search, the enterprise has often been given up in despair. The derangement which a lode suffers from a cross course, is such as to depress or elevate one or other of the walls of the older *lode*, and, consequently, remove it to a distance which to the miner is unknown, although, from the incidence of the one, and the appearance of the rupture of the other, he is able to judge the direction in which it lies. Miners distinguish the fracture of the lode, when it has been removed downwards, by the term *slide;* and when it has been elevated, it is said to be *heaved.* Fig. 316 explains the nature of this fracture of the lode by the occurrence of the *course* here represented by *a*, *b*. In this figure the metallic veins in the superincumbent mass of strata on *a b*, are denoted by *c d*, *e f*, and the sliding of this matter causes them to be thrown out of their course, and take the direction *c′ d′*, *e′ f′*, still maintaining their relative position. By following the intervening *lode* in the point indicated by the fault, the miner is sure to light upon the metallic veins at a distance more or less from the intersection.

Fig. 316.



After the ores are extracted and brought to the surface, they undergo an assortment, by which they are rendered more eligible to the purchaser for smelting. A short reference to this department will be made when treating of the smelting of copper on the large scale.

PREPARATION OF THE PURE METAL.—It may be procured by passing dry hydrogen gas over pure oxide of copper, heated to redness in a tube of porcelain or hard german glass. In this process the hydrogen unites with the oxygen of the oxide of copper, producing water, which escapes at the end of the tube. After vapor has ceased to condense upon a cold porcelain surface held to the aperture, the deoxidation is completed; the current of gas is to be maintained during the time the contents of the tube are cooling. The copper is now extracted in a finely-divided state, and may be melted into a globule.

Copper may likewise be obtained by putting six parts by weight of oxide of copper, and one part charcoal in powder, into a crucible, and subjecting these to a high heat; the metal is obtained as a small button at the bottom. Adding a little borax assists this result.

Pure metal can likewise be obtained from the commercial article, by dissolving it in nitric acid, and adding a little sulphuric acid to the liquid to render it slightly acid; a plate of iron is then immersed in the blue liquor, and the whole left to repose till it becomes colorless. The whole of the copper is now precipitated upon the plate of iron; it is collected, washed with dilute sulphuric acid, to dissolve any particles of iron that may be adhering to it; then aspersed with water, to remove every trace of the acid; and, finally, exsiccated and fused into a button. When prepared according to the first process, and the quantity of oxide is small, the metal appears in films, which reflect the characteristic red of copper; but when the light is transmitted, they are beautifully green.

Pure metallic copper has a fine red color, and in this respect it differs from all the other metals, except titanium; it is capable of receiving a good polish; is so malleable and ductile, that it can be beaten out into very thin plates, or drawn into very fine wires. DANIELL gives its melting point at 1994° Fahr., showing that it is more fusible than gold, but less so than silver. In tenacity it ranks next to iron; a wire of the metal 0·787 of a line in diameter, sustains a weight of 302·278 pounds, according to GUYTON MORVEAU'S experiments. The specific gravity of copper varies with its state of manufacture, from 8·89 to 8·95; the fused metal has a density of 8·89 to 8·91; unignited copper wire, 8·93 to 8·94; ignited wire, 8·93; and flattened wire or sheet copper, 8·95. The hardness of this metal is not very great, it being scratched by calcareous spar. Its power of conducting heat is little more than two and a half times that of iron; its specific heat in relation to that of water, is as 0·095 to 1; and its linear expansion, when heated from 32° to 212° Fahr., as ascertained by LAVOISIER and LAPLACE, is 0·00171733, or $\frac{1}{582}$.

During the time copper is kept in fusion, it absorbs oxygen, if the fused metal be exposed to the atmosphere, whether in furnace or crucible. At a very high temperature it boils, and if it be exposed to the air in this state, it emits fumes, which condense upon cold surfaces into small globules, the nucleus being metallic, and the exterior coating oxide of copper. Exposed to dry air, the metal remains unchanged; but when there is moisture present, it becomes tarnished, and a coat of oxide and carbonate forms upon it. Heated to redness in an atmosphere of steam, no decomposition occurs; but at a white heat, hydrogen is evolved, and oxide of copper formed. Finely-divided copper burns like tinder; and if the flame be intensified by a stream of oxygen gas, it takes fire, and burns with a beautiful green light.

Copper crystallizes in rhomboidal forms, when a large quantity of the metal is allowed to cool; but when precipitated by galvanic action upon a plate of iron, the crystals are octahedral. The glittering spangles in the *avanturin glass*, made some time ago at Murano, near Venice, and which was highly prized for decorative purposes, have been proved by WÖHLER to consist of crystals of metallic copper.

Nitric acid dissolves copper, giving rise to a nitrate of the oxide, and disengagement of binoxide of nitrogen, which, in coming in contact with air, is converted into peroxide of nitrogen; dilute sulphuric acid has no action upon it; but concentrated oil of vitriol, at a boiling temperature, forms with it sulphate of copper, a part of the acid being decomposed into oxygen, which unites with the metal, and sulphurous acid, which escapes.

Hydrochloric acid dissolves with difficulty compact masses of copper; but if they be finely divided, solution is effected with facility.

The atomic equivalent of copper is, in round numbers, 32, and its symbol Cu.

MANUFACTURE OF COPPER ON THE LARGE SCALE. —The production of copper has, during the last fifty or seventy years, exceeded considerably more than treble the yield of equal previous periods. This is especially the case in England; and is to be attributed to the additional impetus which mining has received, to meet the growing wants of the time. The ore from which it is extracted is obtained from Cornwall and Devonshire; but considerable quantities are raised in other parts of England, such as Cumberland, as also in Anglesea in Wales, and in many parts of Ireland. Besides this, copper ore is imported from several parts of Europe; also from South America, Australia, and New Zealand. The quantity of ore annually raised in Cornwall averages about one hundred and sixty-five thousand tons, and in current value amounts to eight hundred and fifty to nine hundred thousand pounds.

All this nearly is smelted in Swansea and its vicinity, a locality which surpasses any other in the world in the extent of its copper foundries. It comprehends, within a radius of fourteen miles, seventeen smelting establishments, which, with one in Anglesea and another at St. Helens, Lancashire, constitute the only works of the kind in the kingdom. The ores, as they are raised out of the mine, are generally too impure to be smelted; but the proprietors, to render them of a greater marketable value, cause them to be *dressed* or assorted, so that the useless material, which the miner unavoidably disintegrates from the strata in which the lode is cast, is rejected as much as possible. On the Continent, the site of the copper works is usually determined by the position and richness of the lodes, in order that the carriage of the ore may not involve too much expense; the dressing of the material at the pit's mouth is carried further in those countries than it is in Cornwall, Devonshire, and other mines of Great Britain and Ireland, notwithstanding that the minerals have to be conveyed from the latter places to Swansea, a distance varying from sixty to two hundred and fifty miles.

Instead, however, of this long carriage being a disadvantage to the founders, the reverse is the case; for several causes unite to render the operation of smelting more eligible at Swansea, than even in the midst of the mineral districts. These are, the long-established plants for smelting, and the adjacent coal-fields, which supply the works with that most necessary and indispensable article in a metallurgical establishment—fuel; a return freight for coal to Cornwall, *et cetera.* Together with these, the harbor offers great advantages to shippers for importing ores from other countries, as well as to coasters, which convey the ore thither from the various mining districts. The average cost of carriage from Cornwall to Swansea is about four shillings a ton, a sum which would not pay for carriage a tenth of the distance inland.

The dressing to which the copper ores of Cornwall and Devon are subjected, is conducted mostly in the following manner:—

The first operation is to separate the larger pieces of ore, called *spalling stuff*, which is for the most part of a good quality; the next batch is called *picking rough*, and is composed of lumps about the size of a cubic inch or more; it is removed by riddling the ore left, after selecting the large pieces, through a stout wire-gauze, the meshes of which are about three quarters of an inch square; what passes through the riddle is denominated *shaft small.* Having done this, the spalling stuff is broken, either by flat-faced heavy hammers, or by rollers, into pieces about the size of the second batch above mentioned, and assorted; pure pieces of ore, called *prills*, are obtained; and the other matters, which are again crushed with the *pickings*, are selected, and the better portions set aside with the prills of pure ore, which are ready for sale.

The remaining batches are now assorted by grinding, and afterwards washing with water, either in an inclined plane, or in a vessel with a wire-gauze bottom, in order to remove the strong particles from the heavier metallic substances.

These processes are designated *jigging* or *buddling*, each of which exerts the desired effect, as it causes the materials to deposit according to their relative specific gravity. When the most part of the impurities have been removed, and the ore is deemed sufficiently dressed for the smelter, it is made up into parcels or heaps ready for sale.

The ores of Cornwall and Devon are generally sold at Redruth, Truro, and other localities near the mines. The mode of sale is by auction, notice of which is given through the public press a fortnight beforehand, in order that the metallurgic value of the ore may be chemically determined, as well by the bidders, as by the agents or proprietors of the mines whence it was taken.

Great care is observed in taking average samples of the various parcels of ores, and also in the assaying of these; and although the results of the assayer are never chemically true in relation to copper, yet they often offer to the smelter a surer indication from which to judge how much metal he can extract, than if a rigorously accurate analysis were substituted.

Since the smelter is so much guided by the assay, as well in purchasing as in reducing the ores, it will be well to treat here of the method by which this is performed.

It has been already stated that the ores of copper are very numerous; but, although this is the case, the extent of their dissemination, and the abundance of their depositions, are very different, copper pyrites being the most abundant, and, therefore, the most important.

Grey copper, and copper glance, are found in large quantities in some localities, and are used for smelting purposes; but the carbonates of copper are of rarer occurrence in this country, though obtained abundantly from Australia and Chili, and generally afford a larger per centage of metal than the other ores just mentioned, while they are easily reduced.

Ores of copper are divided into three classes, according to the nature of the other metals and non-metallic bodies which they eviscerate, and each of these requires a peculiar and distinct treatment, as well for smelting as for assaying:—

The *first class* includes such ores of copper as contain no other metal except iron, and are entirely free from sulphur and selenium, as oxides, carbonates, *et cetera.*

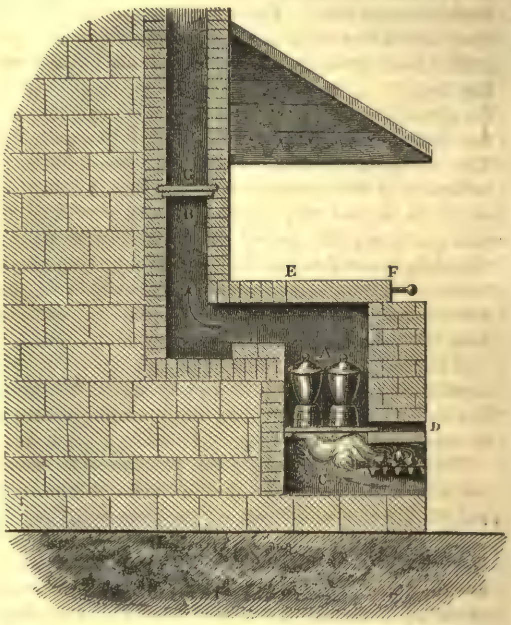
The *second*, those which, in addition to copper, contain iron, sulphur, and selenium only.

The *third class* are those in which various other metals are present in addition to iron, sulphur, and selenium.

To conduct an assay of copper, a furnace capable of producing a high degree of heat is indispensable, besides crucibles, tongs, and such other appendages as are usually employed. One well adapted for this assay is represented in Fig. 317.

In this sketch, the space A is assigned to the fuel and crucibles wherein the reduction is to be effected; this may be sixteen inches in depth, from the level of the cover, E F, to the grate, and from eight to ten inches in breadth. C is the ashpit, which is slightly raised from the floor-level, to facilitate the removal of the cinders; the bars of the grate are introduced through the opening, D, the further end resting upon a proper support fixed in the walls of the furnace. B is the chimney, which should be sufficiently capacious to carry off all the products of the combustion; and it should be entirely kept apart from any other opening. The draught is regulated by the damper, G, which can be pushed in or drawn out by an iron handle. The crucible and assay are introduced into the furnace at the mouth, E F, and placed upon pedestals of brickwork, resting upon the bars of the furnace, after which the opening is closed by the tile, as seen in the figure.

Fig. 317.



Coke broken into pieces about the size of an egg is used in this furnace; but sometimes the fuel may be composed of coke and charcoal, in equal proportions. In this case, the fire-bars should be placed nearer one another than when only the former is employed.

To prevent cracks or fissures forming in the walls of the furnace, by repeated expansion and contraction of the material as it is heated, they are coated over with plates of stout sheet-iron, riveted together, and, if necessary, bound by hoops of metal.

First class ores are easily assayed, especially if they are rich in copper, and the results are satisfactory. The mineral is finely powdered, and about four hundred grains weighed out in a counterpoised crucible; this is thrown into a clean mortar, placed in the middle of a sheet of glazed paper, and about three times its weight of black flux added, and the whole intimately mixed by trituration. The mixture is then introduced into a crucible, and a layer of black flux placed upon the top, and then put into the furnace, which should be raised to a red heat. The mouth of the furnace is left open, and the crucible uncovered, till its contents have settled down into a tranquil state of fusion, after which, the door, E F, is placed upon the opening, and the damper, G, drawn out to increase the draught and raise the temperature of the furnace to its highest point. Ten or fifteen minutes serve now to complete the reduction of the copper. The crucible is then taken out of the furnace with the aid of a tongs, and its under-part gently tapped against a brick, to cause any particles of copper floating in the flux to gravitate to the bottom and form one globule. The crucible is then allowed to cool, broken, and the button of metal carefully detached from the slag, and weighed.

If the ores be not rich in metal, the results are very unsatisfactory, a large quantity of the copper being interspersed in the viscid slag in detached globules or in combination.

When this happens, the usual practice is to mix the ore with a definite quantity of sulphur and an equal weight of borax, and fuse the whole in a crucible.

After the contents of the vessel are quite liquid, the pot is taken out of the fire, and the fluid mass poured into an iron mould having a concave form. The slag or earthy gangue is now to be carefully separated from the button of regulus, so that none of the latter be lost. The regulus is ground and put into another crucible, and subjected to a dull red heat and constant stirring, until all the sulphur is driven off, which is known by taking out the crucible and smelling; there should be no smell of sulphurous acid felt. The heat towards the end may be increased to a bright red, which will in most cases drive off every portion of sulphur. After being entirely deprived of sulphur, it is mixed up with the reducing flux, when it is submitted to the same operation as before described. The per centage of copper obtained by the latter method, is greater than if the ore were at once treated with black flux: it occupies indeed more time, and incurs a little more trouble; but these inconveniences are not to be put in comparison with accurate results.

If any sulphur remains, the button of metal is coated with regulus, and, in consequence, must be submitted to another roasting and fusing again before it can be weighed. Furnace products, and other poor ores, belong to this class.

Ores of the second class generally contain iron, sulphur, and sometimes traces of selenium. The copper in them is determined in the following manner, and also the amount of regulus which they afford to the smelter on the large scale.

To determine the regulus, or matt, as it is sometimes called, three or four hundred grains of the ground sample are taken and fused in a naked earthen pot, with an equal quantity of calcined borax; this flux melts the ore, and the earthy and silicious impurities in combination with it are thrown off in the form of a slag.

After the contents have been melted, the pot is taken from the fire, and immediately inverted upon an iron mould, in the same way as in the last experiment. If the button be allowed to cool in the crucible, it adheres so firmly to the sides, that it cannot be removed without breaking the latter; and even its collection requires much circumspection, which is unnecessary when the matt is poured out while in fusion. The earthy impurities may be separated by first cautiously tapping the button against a hard body, and any matter which might still adhere to it is easily detached by a small hammer having a chisel edge. This part of the operation should, however, be conducted on a tray or large sheet of paper, to prevent the loss of any particles which might fly off. The matt is then weighed, and its quantity determined.

Considerable difference will be observed between the weight of the regulus, as obtained above, and the quantity of ore taken; but it does not entirely consist of gangue, as a portion of the sulphur will be sublimed, leaving the copper in a state of subsulphide.

To ascertain the amount of the metal in this regulus, the first step that must be taken is to expel the whole of the sulphur, by heating the mass in contact with the air; if this part of the operation be not thoroughly executed, all the metal will not be obtained in the assay, portions being retained by the slag, corresponding to the sulphur or sulphuric acid which has not been expelled. The same crucible in which the matt was produced, may serve to heat the latter during the expulsion of the sulphur. It is necessary to grind the substance very fine; and having introduced it into the crucible, the latter is placed in an inclined position in the fire, which should communicate only a very moderate heat, so that the mass will not be agglomerated by fusion. An iron rod should be employed to stir the powder, with the view of bringing every portion of it under the influence of the air. As soon as a sufficient quantity of oxide of copper is formed, the contents of the crucible may be raised to a red heat, as then little fear need be apprehended that the mass will become molten. This heat will likewise eliminate the sulphur from the remaining portion much quicker than a lower temperature; for it decomposes the sulphate of copper which had been formed in the preceding operation into sulphurous acid and oxygen, which latter assists in oxidizing some of the sulphur in the ore into this acid, which escapes. When, upon continuing this roasting, little or no vapors are observed to be evolved, the crucible is heated to whiteness, and maintained at this temperature for some time, to decompose any sulphate which may be present. It is difficult to expel the whole of the sulphuric acid; but by prolonging the exposure of the assay to a white heat, it will be entirely dissipated. Many persons mix, towards the conclusion of the roasting, some powdered carbonate of ammonia with the substance, to facilitate the expulsion of the sulphuric acid: but great care is necessary in following this prescription; for although this salt will most completely decompose the sulphate of copper, producing a sulphate of ammonia, which escapes, yet the evolution of ammoniacal vapors is so rapid at the high temperature of the assay, that portions of the latter are carried away, thus entailing considerable loss, and, consequently, wrong results. When carbonate of ammonia is added, the heat of the furnace should be reduced, so that the fumes escaping may not be so considerable as in the foregoing instance.

Having separated the sulphur, the oxide of copper and other matters of which the substance is composed, are next mixed with three or four times their weight of black flux, and the whole heated in the same crucible in which the roasting was performed. Before inserting the crucible, however, into the furnace, a layer of vitrified borax should be strewn on the top of the assay, to render the contents more fusible, and facilitate the aggregation of all the metallic particles of copper into one button. The fire is applied, gently at first, during fifteen minutes, till the matter fuses; the cover may then be placed on, and the heat urged as much as possible for about the same time. Instead of black flux, many assayists employ a mixture of soda ash, lime, and powdered charcoal, as the reducing agent; the proportions being one hundred and fifty grains of the first, twenty-five grains of the second, and about an equal weight of the third, for a hundred grains of the ore. These substances are intimately mixed with the roasted material in the pot, having a layer of powdered borax strewn on the top of the assay, in the same way as already indicated.

In the mining districts of Cornwall and Devon, the assay of the copper ores is generally conducted as follows:—

Four hundred grains of the compound, finely powdered, are roasted in an air-furnace, as described in the preceding, till a portion of the sulphur is expelled; the pot is then taken from the fire, and allowed to cool gradually. If the assay has a reddish appearance at the top and a blackish underneath, the process is said to be properly executed. The roasted ore is next mixed with a standard flux, composed of five pennyweights of borax, one and a half ladlefuls of lime—diameter of the ladle about three-fourths of an inch, and half an inch in depth—and one measure of powdered fluor spar; this mixture is introduced into the same pot in which the roasting was conducted, and a layer of salt put on the top, and the whole melted to produce a regulus, which is considered good if it yields from forty to sixty per cent. of metal. When the ores are grey copper, black oxide or carbonate, and much earthy impurities are contained in them, sulphur is added, for the purpose of *throwing back the ore.* In either case, the regulus produced is finely ground, and submitted to a second ustulation, to remove the whole of the sulphur, after which it is mixed with a flux of five pennyweights of nitre, ten of red tartar—crude tartrate of potassa—five of borax, and two ladlefuls of salt, the whole being nearly covered with the latter in the crucible: the heat of a good air-furnace is then applied; at first the crucible and contained substance are only preserved at a red heat, till the fusion of the latter becomes tranquil, and after this the temperature is raised as high as possible till the reduction is perfected. Coarse copper is the result of this operation. The slag, or scoriæ, from this operation is ground and carefully examined for copper, which is often diffused through it in small pin-head-like globules, technically termed prills, which are put along with the assay button. If the metal be bright and clean, it is put into a crucible, without any flux, and melted; at this stage the pot is taken out of the furnace and shaken, till the appearance of the button becomes bluish. A refining flux is then prepared, of two parts of nitre and one of white tartar, ground together in an iron mortar, and afterwards stirred with a red-hot iron, till deflagration has ceased. When this flux has cooled, it is finely ground, and five pennyweights of it, together with a ladleful of salt, put with the assay, and the whole again melted; and when this is effected, the copper is poured out into one mould and the slag into another; the latter is again fused with two ladlefuls of red tartar, and the button or *prill* of copper which it affords, added to the one already produced, and the whole weighed.

The preceding is the treatment peculiar to the ores of the third class, containing, in addition to sulphur and selenium, arsenic and other metals. In the first roasting, the sulphides are reduced to the minimum state of sulphuration, and considerable portions of arsenic are expelled. By the second fusion, most of the gangue is thrown off and a rich regulus of copper results, which is divested of its sulphur in the third operation, and finally reduced to metal in the last fluxing. The refining at the end of the process gives a fine red-colored metal free from any impurity. Assays conducted in this way, especially if the ores are poor, such as the Cornish, are rather below the real quantity of copper in the sample. In smelting on the large scale, however, the furnace yield is about equal to that of the crucible. Assays are occasionally taken in the wet way, by grinding a portion or sample of the ore very fine, then weighing out one hundred grains, and digesting in nitric acid for an hour. The acid is diluted with distilled water, and then ammonia added in excess; the whole is then thrown upon a filter, and the precipitate and insoluble upon the filter are washed with water having a little ammonia in it, until the liquor passes through perfectly colorless; the solution is then boiled, when some caustic potash or soda is added; after the ammonia is boiled off, the copper precipitates as a black oxide; when this takes place, the whole is put upon a clean filter, and the filter with the oxide is washed with warm water till the water passing through ceases to blue red litmus paper; the filter is carefully dried, the oxide removed and heated to redness in a china or platinum crucible and weighed; three-fourths of the weight of this oxide is pure copper. Assays taken by this means are always higher than can be obtained by the furnace, averaging from one to two per cent. in some class of ores; but it is a good guide to understand the full value of the furnace operations.

In drawing attention here to the metallurgy of copper, it may be observed that, like many of those manufactures already described, the methods pursued in reducing the ores in different countries vary very much. To enter into a minute description of these, would be, in many instances, a useless, though a colossal labor; to avoid which, the Editor will allude only to the most important of them, beginning with that pursued at Swansea, where, although it produces more than one-half of the copper made use of in the world, the method of smelting seems a complicated one.

The smelter generally distinguishes five classes of ores, which require, on account of the extraneous substances accompanying the metal, to be treated differently.

First Class.—These consist almost entirely of copper pyrites, containing a large proportion of sulphide of iron, much earthy and silicious gangue; the ores are either entirely free from, or contain only small quantities of, oxide or carbonate of copper, and afford from three to sixteen per cent. of metal.

Second Class.—They are similar in composition to the first; but contain from fifteen to twenty-five per cent. of copper.

Third Class.—Copper pyrites, with a large quantity of the oxidized ores of copper, and only very little iron pyrites or other substance, difficultly separated.

Fourth Class.—The per centage of copper which the minerals of this class yield is about twenty to thirty; they are chiefly composed of oxides and carbonates of the metal, and more or less of the sulphide.

Fifth Class.—These ores are generally imported from Chili. They have undergone calcination and fusion before being imported, and form a regulus; they are rich in copper, yielding often as much as fifty per cent., and are free from earthy ingredients.

The most difficultly reduced of these are the first and second classes of ores, which require several preliminary operations to eradicate the iron and sulphur, and other bodies, before the metal can be obtained. By the action of the heat of a reverberatory furnace, considerable quantities of sulphur are expelled in the first operation, leaving the copper combined with a minimum of that element, which it tenaciously retains. In the next, the whole or chief part of the iron is removed by fusing the ores with some silicious matters, which are generally present in sufficient abundance. In this fusion the copper manifests a greater affinity for the sulphur than the iron, which is readily oxidized by the air, and the oxide thus produced is taken up by the silicious matters, leaving the matt of sulphide of copper behind, rich in metal, but still containing some sulphide of iron. By a further roasting—the length of time according to the quantity of sulphur and iron present—a slag is thrown off, in which is all or most of the iron, leaving the matt of sulphide of copper richer than what was produced in the foregoing processes. It is thus by successive calcinations that all the iron and sulphur are removed, leaving a fusible mixture, called black copper, which is afterwards refined. All these operations may be embraced under the following heads, viz.:—

First, The calcination of the ores by which the metals are reduced to a lower degree of sulphuration.

Second, Melting the above product for coarse metal; in this operation, a quantity of slag from succeeding operations is added to assist fusion.

Third, Calcination of the coarse metal.

Fourth, Melting of the calcined coarse metal with rich ores of the fourth class, to produce *blue metal.*

Fifth, Roasting of the blue metal, by which *regulus* is produced.

Sixth, Re-melting of slags obtained from the foregoing operations to recover their copper. These slags are put into the second or fourth operation by some smelters, in which case the sixth operation is avoided.

Seventh, Roasting for white metal, or sponge *regulus.*

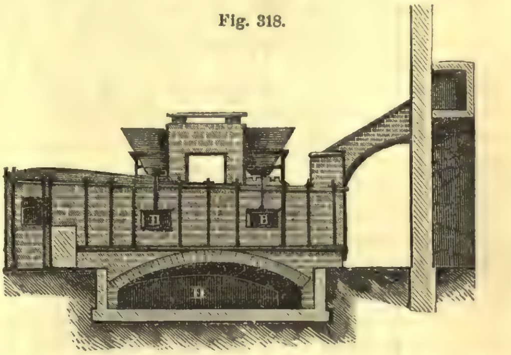
Eighth, Roasting for regulus, or coarse copper.

Ninth, Roasting for blistered copper.

Tenth, Refining, and production of tough malleable metal.

There are some ores that are so easily reduced that the fifth operation will produce a result equal to the sixth with other ores, in which case one or two of the processes are dispensed with, as the smelter may deem proper.

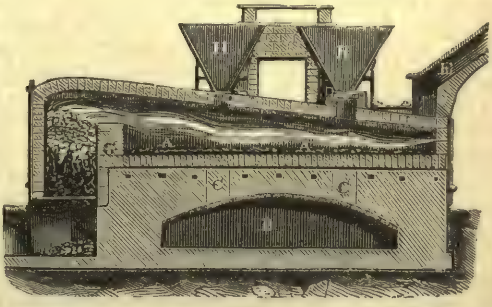
Fig. 318.



It is evident that in all these processes, where heat has so much to perform, the furnaces and the fuel are deserving of great consideration.

The furnaces used in copper smelting are always of the reverberatory description; but they vary in point of dimensions.

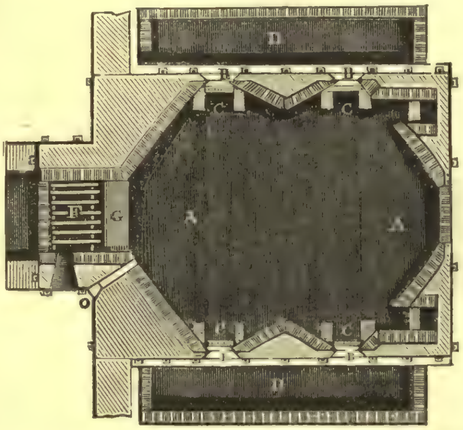
Fig. 319.



Figs. 318 and 319 represent a front and sectional elevation of the roasting furnace, where the ore undergoes the first operation; and Fig. 320 a plan of the same. The bed, represented in the figures by A A, is of an elliptical form, truncated at the extremities of its great axis. In this figure, however, the walls deviate from the elliptical outline near the openings, for the purpose of facilitating the removal of the charge. It is constructed of firebrick, set endwise in a bed of refractory fireclay; its length is about sixteen feet, and its breadth thirteen and a half. Beneath this is a vault, D, serving as a receptacle for the roasted material, which is drawn out by the furnace-men, through the openings, C, C, behind the working doors, B, B. The arch of the furnace, the mean height of which is about two feet from the bed, contracts rapidly towards the flue holes, E, by which the gases evolved from the combustible products pass off to the chimney. F is the fire-grate, and G the bridge of the hearth. Air is admitted into the furnace by means of openings, such as O, made near the fire, and capable of being closed at pleasure.

In other forms of the furnace, there is a channel made in the bridge, G, which opens outwardly, for the purpose of supplying an equalized current over the whole of the hearth. On this account, and also because the current is heated in passing through the bridge, this construction is more effectual than the other.

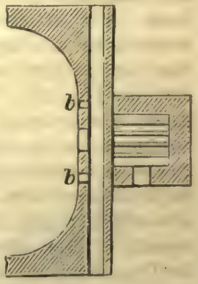
Fig. 320.



H H are two large sheet-iron hoppers, with sliding doors at the bottom; into these the ore to be roasted is put; and, when required, it is let into the furnace by drawing back the slides at the bottom. Exteriorly the furnace is bound with strong upright and horizontal bars of iron, to give it firmness. The fuel consumed is coal, and the selection of the quality of fuel is a most important element in the operations of smelting copper. It should produce a swelling in the operations of burning, and form a cake of a spongy texture, easy of combustion, and giving out a great quantity of heat, which is to be extended from the fire to the hearth to fuse the ore. It should have a sufficient quantity of ash to form clinkers, which are made very subservient to the structure of the fire in a copper-smelting furnace, and it should be free from sulphur, as that substance would readily combine with the copper and deteriorate it. Coals possessing all these qualities are found in great abundance in Swansea and neighborhood, and as one quality may be used with more advantage than another for different operations, so different pits, in different localities near Swansea, give the various qualities, which may be used either separate or mixed as the operator thinks fit.

The bars of the furnace, which are usually from four and a half to five feet in length, and about three inches square, are placed at a considerable distance apart, and pieces of slag or bricks thrown upon them. Upon this the fire is made, and as the carbonaceous matter is consumed the earthy portion fuses and forms clinkers; but, meeting the upward current of cold air, it contracts, and numerous fractures sufficient for the passage of the current form in it. As this matter accumulates, the attendant removes a portion from the bottom, but retains a bed of from twelve to eighteen inches in thickness upon the bars. By this means none of the coal is lost; the bars of the grate will serve for an almost indefinite period, as the mass of clinkers preserve them from burning, and the fire burns well. Openings or holes are made in the clinkers to give draught, and produce what is necessary in the roasting of the ore, to have it covered with a sheet of flame over the hearth. As the stream of air rushes through the grate and fire, it is deprived of oxygen by the ignited coal, and the gases evolved over the bridge are nitrogen and carbonic oxide; scarcely any carbonic acid is produced during this part of the combustion. The air-holes represented in the foregoing drawing now begin to act their part, for as the fresh stream of air rushes in through them, and meeting with the half-consumed carbon at an elevated temperature, a fresh combustion takes place, in which carbonic acid results, and a flame is produced along the hearth of the furnace. In effecting the latter, the modification of the air-passages, according to the plan of Vivian, is much more appropriate, as will appear from an examination of the annexed figure of the bridge, showing the division for the admission of the oxidizing agent. During combustion the excess of the oxygen unites with the volatile oxidizable bodies, and these pass off with the other products. Each furnace is watched by two men, who work night and day, and in the period of twenty-four hours calcine about seven tons of ore; however, this depends upon the nature of the ore, some kinds requiring twelve hours, others only nine hours. By obtaining a proper mixture of ores, and giving only nine hours, a great saving is effected. This practice is now very generally adopted in Swansea.

Fig. 321.



The charge, which amounts to three or three and a half tons, is let into the furnace by removing the plates which cut off the communication between the hoppers and the interior; and as soon as the whole is introduced the plates are again restored, and the ore spread evenly on the sole of the furnace by means of iron rakes working through the doors. This being done the doors are closed, the fire is replenished with the proper allowance of coal, and the draught through the clinkers established by abstracting a few of them if required, or loosening them by means of an iron rod made in the form of a pick at the end, the door being closed, and the coals for the next fire being shovelled against it. The fire now begins to exert its influence upon the ore, which, ultimately, is to expel sulphur as much as possible and produce oxides instead. To effect this much care is required in its management; for if the fire be too elevated, the sulphides present would enter into fusion and form a vitreous mass, offering only a little surface to the flame, and, therefore, rendering the roasting imperfect, and entailing much trouble besides, for the fused matt is apt to adhere to the walls of the furnace.

The precaution of keeping the fire at a moderate working temperature is to be more attentively observed during the first six or eight hours of the roasting, that is, as long as the ore contains an excess of sulphur and other volatile bodies; and after this, to the end of the operation, the heat may be increased as the tendency of the charge to agglutinate becomes less. At first the aqueous vapors, and some sulphurous acid, are eliminated, the latter becoming more abundant during the first two hours, after which the doors are opened, and a fresh surface presented to the flame by furrowing the charge in parallel lines with a long iron tool, called a *rabble*. Having done so, the fire is again charged with a fresh quantity of coals, the grate put in proper order for burning the fuel, and the combustion of the metals and non-metallic elements of the ore allowed to proceed without interruption. The chemical action, thus taking place in the interior of the furnace, greatly assists in expelling the arsenic and sulphur contained in the ore, by subliming a portion of them, and bringing their vapor more readily in contact with the current in the furnace. The work of rabbling the ore with rakes and bars, and firing, takes place at the end of every two hours, till as much of the volatile products as can be expelled by the heat is driven off and oxygen substituted. This happens, as already stated, in about eleven or twelve hours; but towards the end of the calcination the fire is urged so, that when it is time to draw the charge the furnace is at its highest degree of heat. The doors are now opened, and the plates covering the openings, C C, Fig. 322, removed, in order that the calcined mass may be raked through them into the vault, D. This part of the operation is the most laborious and injurious to the health of the workmen, for, in addition to the great heat, they have to endure a worse evil in the shape of sulphurous and sulphuric, and often arsenious, acids; for as only half the sulphur is expelled whilst in the furnace, the ore coming in contact with the air at a high temperature evolves large volumes of the forementioned gases, which are disseminated in the surrounding air, rendering it almost irrespirable. Immediately after the calcined batch is cleared out, another is introduced from the hoppers, and the furnace being at a red heat, causes the evolution of aqueous and sulphurous gases at once. The material is spread out evenly, and after an interval of about fifteen minutes, during which it will have reduced the heat of the furnace to the proper working pitch, the firing is renewed, and operations are again proceeded with as already recounted.

Very little loss is sustained during the calcining, as the quantity of oxygen assimilated nearly balances the loss in sulphur, *et cetera*. According to M. LE PLAY'S analysis of the substances before and after calcination, the numbers in the annexed tables give a fair average of the action of the fire upon them.

		Total weight.	Centesimal weight.
Crude Ore.	Oxide of copper isolated or combined,...	3·2	·374
	Copper pyrites,..........................	194·2	22·710
	Iron pyrites—bisulphide of iron,.........	191·9	22·442
	Various sulphides,.......................	8·7	1·001
	Oxide of iron,...........................	5·2	0·608
	Other oxides,............................	2·3	0·269
	Quartz and silica,.......................	294·4	34·428
	Earthy bases,............................	16·0	1·871
	Water and carbonic acid in combination,	4·2	0·491
	Oxygen consumed,.........................	135·0	15·806
		855·1	100·000
	Products.		
Calcined Ore.	Oxide of copper,.........................	46·2	5·401
	Copper pyrites,..........................	96·0	11·228
	Bisulphide of iron,......................	95·8	11·226
	Other sulphides,.........................	5·1	0·600
	Ferric oxide,............................	100·2	11·718
	Other oxides,............................	5·2	0·608
	Sulphuric acid in combination,...........	9·5	1·108
	Quartz and silica,.......................	294·4	34·408
	Earthy bases,............................	16·0	1·874
Gaseous products,	Sulphurous acid,...	182·5	21·338
	Water and carbonic acid,............	4·2	0·491
		855·1	100·000

No account is here taken of the arsenical products, which are nearly always present in greater or less quantities. The matters which are evolved from the calcining furnace may be set down as consisting of—

The vapor of water,
Sulphurous acid,
Sulphuric acid,
Arsenious acid and arsenical vapors,
Fluoride of silicium and other volatile compounds of fluorine,
Solid matter, mechanically conveyed by the draught into the flue,
Carbonic acid, *et cetera.*

All these are the result of the combustion of the fuel and other matters of the ore under operation; the water arises from the oxidation of the hydrogen of the coal, as well as the expulsion of the moisture in the mass. It is this, acting on the sulphurous acid arising from the sulphur in the presence of the oxygen in the furnace, which gives rise to sulphuric acid. The arsenic and its compounds are contained in the ore, and are expelled as such; but the former undergoes combustion in part, and forms arsenious acid. By the action of the silicious gangue upon the fluoride of calcium, fluoride of silicium is produced. Hydrofluoric acid is also generated, as is evidenced by the action of the gases upon glass. DUMAS accounts for its occurrence by the supposition that fluoride of arsenic is formed, which, in contact with the vapor of water, becomes converted into arsenious and hydrofluoric acids.

All these vapors pass off into the atmosphere, and from their enormous quantity, and their destructive influence upon vegetation, cause serious damage to the surrounding district. Taking the average quantity of ore smelted at Swansea annually to be two hundred thousand tons, consisting chiefly of copper pyrites, the total amount of sulphur contained in them may be estimated at from forty-five to fifty thousand tons; all this, together with the other gases already alluded to, are eliminated into the atmosphere in the shape of sulphurous and sulphuric acids, of which from ninety to one hundred thousand tons are produced. Such an evolution of destructive, noxious vapors, as takes place in copper smelting, especially where a large number of works is located, with the immense volume of carbonic acid accompanying them, and which is no less deleterious to animals, makes it a matter of surprise how either animals or vegetals can live in their neighborhood. Certainly the face of nature in the vale of Swansea bears indelible traces of its ravages; but for this the founders compensate by subscriptions raised among them. The copper smelters are to blame, however, for having, during a series of years, permitted so much valuable material not only to go to waste, but to injure their agricultural neighbors. Averaging the cost of sulphur at seven pounds a ton, the loss which they have sustained in this article alone is not less than one hundred and twenty thousand pounds a year; but if converted into vitriol, the amount which it would annually return would swell to four hundred and forty or fifty thousand pounds sterling, a sum which would reward enterprise with a princely fortune in a few years. True, some outlay would be required to take advantage of this source of wealth, but still the work is so feasible, that no insuperable difficulty stands in the way of the enlightened capitalist who might devote his energies to this beneficial object.

Of late some exertions have been made to condense the poisonous fumes, in order to prevent nuisances; and within the last few years efforts have been made to prevent the injury more effectually, by erecting vitriol chambers in connection with the calciners, in order to condense the sulphurous acid, and thereby convert the source of the nuisance into vitriol and a source of profit. The first method attempted was by the erection of tall chimneys, for the purpose of conveying the vapors so high into the atmosphere, that, meeting with a vast body of air, they might be so diluted and neutralized by the ammonia as to render them in a great measure inert. Another mode of effecting this end has been tried by the construction of long galleries, or troughs, holding water, and covered by perforated slabs of stone placed horizontally, over which a stream of water was kept constantly flowing. All the volatile products from the furnaces were made to traverse this gallery, where, meeting with the percolating water, much of the sulphurous acid was absorbed. It seems, however, that this condensing medium interfered with the draughts, or was costly in its erection, for it never came into general use, or entirely answered the desired purpose.

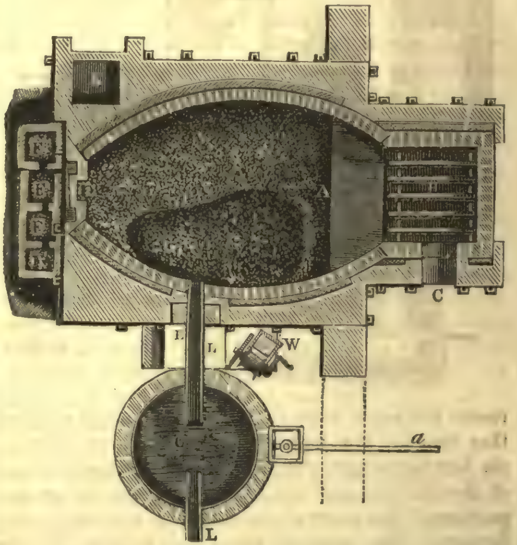
The ore being cooled, is conveyed in barrows out of the chamber represented in the foregoing figure, to a proper place, whence it is taken to undergo the second calcination.

Second operation.—In the first, all that is effected is to expel so much of the sulphur as will leave the copper in the form of a sub- or di-sulphide, with a corresponding quantity of oxide of copper. The iron and other fixed matters remaining are to be removed in part in the second calcination. The temperature employed in this process is higher than in the foregoing, and the charge operated upon is much less. In the presence of silica, iron enters into combination with it at a high temperature, and forms a scoria which may be removed by mechanical means; it is thus that the whole of this metal is abstracted from the copper. Sometimes the roasted ore contains a sufficient quantity of silica to produce the combination; but it is customary, notwithstanding, to add a fusible slag from some of the succeeding operations, and which is rich in copper, in order to decompose the matter more thoroughly. This is very necessary, as the slag which is thrown off during the fusion is usually cast aside as worthless; it is sometimes, however, broken, and any portion of copper it may retain picked out, and the remainder discarded. Latterly, however, it is used in the preparation of tiles, slabs, and bricks suitable for building.

Not less than 0·4 or 0·5 per cent. of the total weight of the copper in the ore escapes in this slag, and becomes useless to the smelter, even when the greatest care is exercised.

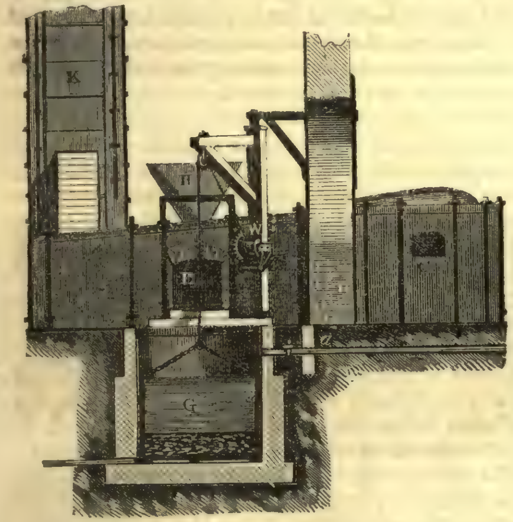
Figs. 322 and 323 represent the furnace employed. The first of these is a plan horizontal with the bed of the furnace, and the second a side view, showing the tank in section and the machinery appended to it. It is no more than one-third the size of the calciner already described, and differs from it further in having no side doors, except an outlet which conveys the matt into a proper recipient. A is the bed or hearth where the charge is elaborated; this inclines towards the outlet already mentioned, and designated here by L, so as to form a kind of basin. B shows the furnace bars, C the fire door, and D D the working door of the furnace opposite to the fire. E is the door of the outlet, but this is securely closed during the period of working the charge. F, F, F are sand moulds, into which the slag is raked out; H is the hopper into which the materials constituting the succeeding charge are put whilst one is being worked off; G is a tank kept full of

Fig. 322.



cold water by a supply-pipe, *a*, and emptied by another leading from it at the bottom. In this tank a frame of wood or iron is immersed, the bottom of which is composed of a stout wire gauze, the whole being connected by ropes or chains to a winch, W, which serves to lift the frame out of the tank when necessary. K denotes the chimney, which exercises a greater influence upon this than the preceding furnace. This is necessary, because the heat required in this second operation is much higher than in the first. The fire, which in both has about the same dimensions, is constructed upon a mass of clinkers, as already described. The charge for this furnace consists of twenty-one hundredweight of calcined ore. Lime or fluor spar is also employed, the quantity being about one and a half hundredweight. Some smelters prefer larger furnaces, capable of fusing double the quantities here given, the proportions and the operation being the same. In addition to these, about three and a half hundredweight of slag, obtained from operations four and five, following, are used, as well to render the whole more fusible, as to obtain the copper they contain; thus making in the whole about twenty-six hundredweight. All the ore and the finer portion of the flux are put into the hopper, and the coarser portions of the latter are thrown in at the door of the furnace. The man attending the furnace fills the hopper during the fusing of the charge, and has all the materials ready, so that when the furnace is tapped, a new charge is instantly let in that no heat be lost.

Fig. 323.



As soon as the former part from the hopper is introduced into the furnace, the attendant spreads it as quickly as possible upon the bed or hearth, and then throws in interspersedly the larger pieces of slag. When all has been added, the door is carefully closed, and made secure by luting, as also the side opening; the furnace-man then replenishes the fire, and refreshes the draught by removing some of the clinkers, and opening the crevices with the pointed iron. The charge is unmolested for three hours and a half, only that the interior is observed from time to time, to see that the fusion progresses favorably. Fresh fuel is thrown on at the end of an hour and a quarter, or less, as deemed requisite; the quantity being proportioned to the allowance for the working of each charge of eleven hundred one quarter, or thirty-four and a half hundred of coal for every twelve hours. In half an hour after the spreading of the ore on the hearth of the furnace, the slag begins to fuse, and in a very short time it forms liquid channels, or little lakes, in the mass. Soon after, the fused matter extends over the whole hearth, from the combination of the iron and silica present, into a very fusible silicate of that oxide. As the quantity of liquid matter increases, it becomes agitated from the evolution of sulphurous acid, produced by the oxidation of the sulphide of iron, a silicate of iron being formed instead. Fluoride of calcium also brings about the fusion more readily, and the decomposition of this compound in the presence of silica, by which fluosilicic acid gas is disengaged, favors the intimate mixture of the materials, and aids in the expulsion of the arsenic. At the end of the time already mentioned, the whole of the charge is almost melted, except some portions of slag which may remain at the sides of the furnace, and gas ceases to be evolved. The furnace-man now opens the door, and by a long rake rabbles the whole charge, by which means it is brought into contact with the fused mass, and thereby dissolved. He now urges the fire to its highest heat, which is maintained in that state for about half an hour. During this time the moulds are being prepared by spreading the sand evenly, and then digging out a form of a mould. When this is done, the tap-hole is carefully opened to draw off the fused matt, which, from its greater specific gravity, lies at the bottom of the fluid mass. When the chief portion has flowed out into the tank, the hindmost door is opened, and the slag, which is in a semi-fluid state, is drawn out and falls into the mould beneath the door, and thence flows into those to the left and right. Although the most part of the matt, from its greater fluidity collects in the basin of the hearth, still considerable portions are retained in the viscid flux; and it is to obtain these that the latter is collected into the moulds. When drawn out into the sand the scoria still remains fluid, and the particles of copper which may be retained in it, having a greater gravity, fall to the bottom. As the moulds at either side of that under the door are filled by the overflow of the latter, it is found that during the short period in which the fluid material is detained in it, most of the copper falls to its bottom, and what is not retained is deposited in those next to it, leaving the exterior blocks comparatively free from the metal; the latter are kept hot as long as possible, so that any matt may have time to settle more completely. With this intention they are covered with a layer of sand, and to prevent a draught a plate of iron is reared up before them. When they are cold, they are taken from the moulds to another part of the factory and there broken, in order that the portions containing the copper may be collected and added to the next charge. As some of the blocks are richer than others, the workman takes the precaution to mark them in the order they were cast, at either side of the central one. In drawing off the scoria from the matt, much skill—acquired only by practice—is necessary. To the practical workman it is very simple, as he is well acquainted with the different degrees of fusibility in the matt and flux. In no instance is the whole of the slag entirely skimmed off; for if this were done, the fluidity of the metallic bath would be in some measure lessened, as a portion of oxide of copper would be formed on its surface, and it would not flow out of the furnace. A portion of the scoria is likewise left on the hearth, in order to resist the corrosive action of the ore upon the furnace. The volume of matt of cupreous matter from each charge is about twelve to fourteen hundredweight.

Much care and experience are necessary on the part of the attendant—known as the *furnace-man*—in this operation, as the success of the work depends upon his maintaining a proper degree of heat; and it is only by close observation that this can be accomplished. The suitable temperature is ascertained by looking through a hole in the furnace-door and observing the glow of the interior, when, if it be of the characteristic brightness, the necessary intensity is acquired. If, however, sufficient incandescence should not be apparent, it may be concluded that either too much fuel has been put on the fire, or that it must have burned too low, or that the draught is defective. In the event of any of these being the case, the course followed is to open the crevices through which the current of air enters and remove a few clinkers; then, if necessary, a small quantity of fuel is thrown on, and as soon as this is thoroughly ignited, and has become red, a further supply is repeatedly added, till the heat is brought to its proper pitch. This method is resorted to also when the command of fuel is limited. The quantity of air passing through the fire should likewise receive attention, lest it may be more than sufficient for the combustion, because in that case it shortens the flame, and the materials are not so thoroughly heated as when only the combustible gases traverse them. Four hours are required to work off each charge, so that while one is being operated upon in the calcining furnace, four are fused in this; but as the latter are much less in quantity, the work of the two furnaces nearly balances each other. During the four hours of fusion, the interior of the furnace must be kept at an elevated temperature, to retain the contents in perfect fluid condition. If this heat be not maintained, there is danger of the ore adhering to the base of the hearth, a circumstance which entails much expense in eradicating the solidified mass, and bringing the furnace to its proper working point. Every furnace is looked after by two men, each attending twelve hours, and the operations never cease night or day during the week till Sunday, from which time till Monday morning following all remain uncharged. In this period they are not allowed to cool, but one or two men maintain the fire, so that they may be ready to receive a charge as the first thing requiring to be done at the beginning of the week. The night-shift is taken alternately by the men.

To those who have been working at these furnaces for some time very little directions need be given, so long as the ore operated upon remains of a uniform composition, as well in metal as in slag, for they have in that case only to add the proper quantity of fluxing matter at once, and proceed as just detailed; but any alteration in the nature of the ore, whether it be in the quantity of metals or in the amount of gangue, causes a derangement, which must be righted by the inspector of the foundry, aided often by a complete quantitative analysis of the ore. When poor and rich ores are at hand, the easiest course, and that which is usually adopted, is to mix them in quantities calculated to produce a compound, the mean composition of which is such as is generally operated upon; but if the materials cannot be thus regulated, the flux must be apportioned to produce the desired effect. Much care is taken not to have an excess of scoria, lest too much copper may be mechanically retained by it, and a loss sustained. For this reason fluoride of calcium is not used, except it is considered that the gangue is rather difficultly dissolved, and the fused scoriæ from the succeeding operations are not on those occasions added at once, but only in successive small portions at a time, followed by a rabbling, till the whole contents have arrived at the desired fluidity. Having acquired this knowledge in the first charge, the proper fluxing materials are afterwards added at once, as long as the class of ore in question is to be worked.

The chemical metamorphoses going on within the furnace are few and simple—merely the formation of a silicate of iron, and the consequent evolution of sulphurous acid and sulphur, with a few other changes. It nearly always happens that sufficient silica is present in the ores, at least in those raised in England, to take up all the iron; but where this is not the case, a proportionate quantity of quartz sand is added. Oxide of iron manifests a great affinity for silicic acid at a high temperature, and combines with it, under this circumstance, in preference to any other volatile acid; hence, with the combined influence of air and heat, the iron present in the ore, in the state of sulphide, is converted into silicate of iron and sulphurous acid. It is necessary, however, to bring the substances into a very intimate contact before this combination can be induced, and hence the reason for adding a fusible flux. Silicate of iron already formed and fluor spar are the most eligible to the smelter, as they readily fuse and form a bath in which the combination of the iron and the silica is effected. This affinity of the silica for iron induces the decomposition of the portion of iron pyrites left after the first calcination; the metal becomes oxidized by the current of air passing over it, and the sulphur is expelled partly as such, and partly as sulphurous acid. A commotion is caused by the evolution of these gases, which greatly favors the chemical action; and in cases where fluor spar is employed, it is maintained after the sulphurous bodies cease to be evolved. The nature of the action in the first instance might be rendered thus:—

$$\underbrace{Fe_2O_3 + 2\,FeS}_{\text{Sesquioxide and sulphide of iron.}} + \underbrace{CuO + 2\,CuS}_{\text{Oxide and sulphide of copper}} + \underbrace{O_6}_{\text{Oxygen.}} + \underbrace{4\,SiO_2}_{\text{Silicic acid.}} =$$

$$\underbrace{4\,(FeO, SiO_2)}_{\text{Silicate of iron.}} + \underbrace{3\,CuS}_{\text{Matt of copper.}} + \underbrace{3\,SO_2}_{\text{Sulphurous acid.}}$$

The manner in which the fluor spar, or fluoride of calcium, acts, is by parting with its fluorine to the silica which should be present in excess, thus giving rise to gaseous fluoride of silicium, the lime being oxidized by the latter body, thus :—

$$\underbrace{2\,\mathrm{Ca\,F}}_{\text{Fluoride of calcium.}} + \underbrace{\mathrm{Si\,O_2}}_{\text{Silica.}} = \underbrace{2\,\mathrm{Ca\,O}}_{\text{Lime.}} + \underbrace{\mathrm{Si\,F_2}}_{\text{Fluoride of silicium.}}$$

Beyond rabbling the materials by the effervescence caused by the expulsion of the fluoride of silicium, and the fusion of the fluor spar at the beginning, it would appear that no effect is produced by it, so that the most important part of the decomposition rests upon the union of the iron and silica, as shown in the previous formula. The matt is a mixture of sulphide of copper, with portions of oxide of that metal, and sulphide of iron still in combination. As soon as the furnace is emptied, the next charge which the men, during the working of the preceding one, had deposited in the hopper, is introduced and spread out as detailed, to be treated in the same manner, and the matt produced from the preceding charge, and which has been reduced by contact with the cold water in the tank to small grains, is raised out by means of the winch, and conducted to the depôt or warehouse where it is kept. The pigs of scoria are broken in the adjoining yard, and the richest returned to be fused over again in another charge. The presence of copper is readily discernible in the fracture of these, when it exists in quantities varying from one-eightieth to one four-hundredth of their weight, and its quantity to within one-thousandth determined by the eye of the experienced worker. After selecting into a heap the richer portions, or such as retain appreciable quantities of copper, to be returned to the furnace, the remainder is discarded, and mountains of it may be seen accumulated near some of the large smelting-houses, and conveyed from the works by rail and steam, at a cost to some of the large works of from three thousand to five thousand pounds annually. Great quantities are used for roads and walls.

Third Operation.—The granulated matt from the foregoing process being taken from the tank and dried, is weighed and conveyed to the furnaces destined to receive it, in order that it may undergo the third process. These furnaces resemble in size and outline, those devoted to the calcination of the crude ore, and the charge of matt is, as in the former case, about three and a half tons. This quantity is thrown into the hopper surmounting the dome of the furnace, and let down into the bed in the usual way by drawing the slide, and afterwards spread out upon the sole in the same manner as was done with the crude ore. A similar purpose is here entertained as in calcining the crude ore, namely, the expulsion of the sulphur, and the production of oxidized bodies; but as the chief part of the gangue is removed in the preparation of the matt, these results will now be much more effectually produced than when all the impurities were present. Great attention must here also be given to the fire in maintaining its heat within bounds, so as to keep the material at such a state of ignition as will facilitate the expulsion of the sulphur, but is insufficient to fuse the mass, and prevent its oxidation in an effective manner. On the whole, the heat is much higher in this than in the first operation, more especially towards the end of the roasting, which occupies about twenty-four hours. For this purpose twenty-one hundredweight of coal are required, or three and a half quarters of a hundred per hour. During the first two hours the fire is kept low, and then as the sulphur becomes eliminated it is increased regularly, so that in the course of about twelve hours the ore has attained an incipient red heat. At the end of eighteen hours the whole of the interior of the furnace should be at a cherry-red heat; and at the close of the operation, the temperature of the whole should have assumed a bright redness. Every two hours the action of the fire is accelerated by a rabbling of the charge, by which a fresh surface is exposed to the flame, and the sulphur compounds become decomposed. Much importance is attached to the proper calcination of the matt in this operation, and, therefore, it is not left to the discretion of the furnace-men; inspectors are appointed to attend some few furnaces, and see that the work is duly attended to in every particular, especially the rabbling, which takes place at an interval of every two hours. If this be neglected, the whole of the sulphur will not be expelled in the form of sulphurous and sulphuric acids. An elevation of the temperature is not so injurious to the success of the operation as the contrary, because the tendency of the ore to form masses will check the furnace-man's inattention in this respect, as he would have to break them up afterwards—a very laborious operation; but when an incipient heat is applied, there is little danger of the charge agglutinating, and the rabbling is easily performed; but this is at the risk of not expelling the sulphur in sufficient quantities.

The change produced by the third roasting is expressed in the annexed tabular numbers, which show the relative weight of materials taken :—

Coarse metal,	0·804
Oxygen derived from the atmosphere,	0·196
	1·000

The products obtained by calcination are as under :—

Calcined coarse metal for the succeeding operations,	0·783
Sulphurous acid and sulphuric acid,	0·217
	1·000

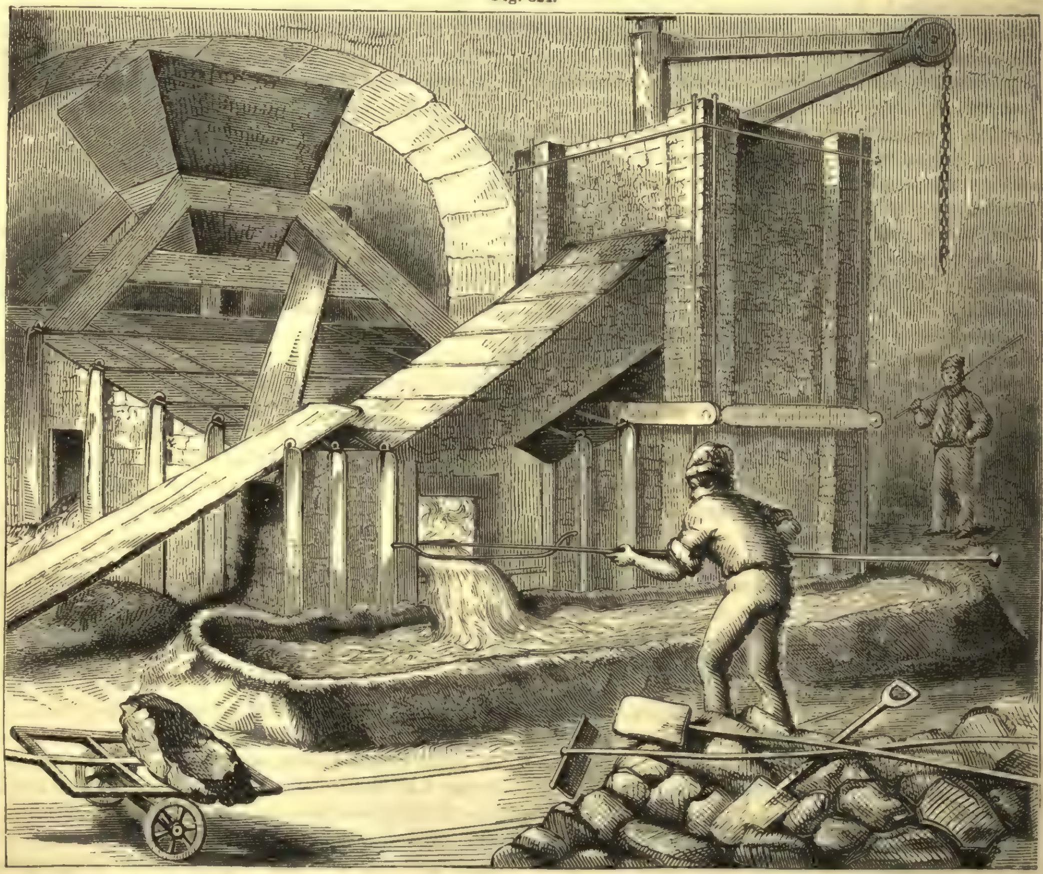
The physical appearance, as well as the chemical composition of the ore, has altered; it suffers a diminution in bulk, and instead of being of a dark grey, it assumes a black hue, appearing brownish under reflection. Throughout, the mass is friable, but where the grains are large and more solid, the exterior parts are easily reduced to powder, and the interior nucleus is hard and compact. After the whole charge is properly calcined, it is raked out through openings immediately inside the working doors, and falls through into a chamber under the hearth. This is called *calcined coarse metal*, and is, as soon as convenient, submitted to the next process, to procure what is termed *blue metal*.

Fourth Operation.—The procedure in this stage of the work is analogous to the fusion for *matt* in the second process. It has for its object the removal of the iron, and the production of pure sulphide of copper, or at least as rich a compound as possible. In doing so it offers an opportunity for operating upon the other ores of the *fourth* class, which contain little sulphide of iron, and the copper of which is in the state of sulphide and oxide. Although the work in this process is simple, yet it is more difficult of management to arrive at satisfactory results than any other yet described. The chief point to be attained is the blending of the calcined matt and the crude ore already mentioned, in such a way that the oxide of copper in the whole may be converted into sulphide by the impurities or sulphide of iron in the latter. It becomes a more difficult matter to apportion these, considering the nature of the charge, for it is compounded of rich slags from succeeding operations, of scales of oxide of copper from the rolling mill, of crude ore of often very variable composition, and of the calcined product from the preceding calcination, together with silicious matters from the furnace walls and sole. All these may be represented in the charge as annexed:—

Calcined coarse metal from the third operation,	0·559
Crude ores,..................................	0·243
Copper scales, *et cetera*,..........................	0·007
Scoria from the ninth operation,..................	0·060
Scoria from the tenth operation,..................	0·024
Furnace waste from the second and fourth to the tenth operations,..........................	0·060
Earthy matters: sand,..........................	0·041
Earthy matters: bricks,..........................	0.006
	1·000

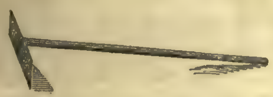
The only criterion which workmen have for their guidance is deduced from their observation on the first charge of a batch of these products. Practically the best decomposition is obtained, taking all allowances for the inequality of the oxygen and sulphur compounds into consideration, when the fusion is prolonged; and it has also been found that a better yield in quality, as well as in quantity, is ultimately produced when from four to eight per cent. of iron are retained in the matt, and from three to five per cent. of copper pass off in the slag. This slag forms a very important article in the operations of the smelting-house, as it contains a very large quantity of oxide of iron, having generally about fifty per cent. of protoxide of iron, and about three per cent. of oxide of copper, combined with silica, which, when added to the calcined ores in the first fusion, forms a most excellent flux for the ore, which, were it not obtainable, extra calcining of the ore would be necessary, or flux of lime or fluor, which in all cases is expensive besides. This enriching of the slags with oxide of copper is not an inconvenience in the work; nor is any loss suffered in consequence, but a saving, as all the slags produced in this, as in other processes, are fused in the second operation, and the copper in them recovered in the matt, which it improves and enriches. Should too much oxide of

Fig. 324.



copper be permitted to remain in the slag, it would react upon the sulphide of copper, and reduce a portion of it to the metallic state. When this happens, the metal is usually of a bad quality. Indeed, it is the chief aim of the furnace-man to prevent this; dividing his attention, however, with the production of the purest white metal that is possible under the circumstances. Fig. 324 is a view of the furnaces in operation at the copper works of Messrs. **Newton, Keates, and Company**, at St. Helens, Lancashire. It is similar to that in which the second fusion is performed, except that there is no cavity in the hearth, but a gentle slope towards that side in which is the tap-hole by which the fused material is run out; the fire is managed in the same way, but a much higher heat prevails on account of a larger consumption of fuel. The materials, in the proportion indicated in the table already given, or in such quantities as the judgment of the furnace-man suggests, are introduced through the hopper, and spread out in the usual manner; the larger portions, especially the scoriæ, are thrown in at the working door, and distributed evenly over the surface of the charge, which altogether weighs about thirty-two hundredweight.

When this is done, the doors are closed, and even luted, and the fire regulated to enable it to give out the required heat. Calcination of the surface then proceeds, but very little gas is evolved. At the expiration of an hour incipient symptoms of fusion appear, as well in the softening of the mass as in the evolution of the gaseous matter; the fusion of the whole progresses gradually till about three hours after charging, when it appears in two layers, the one as yet undissolved, floating on the fluid portion. All the volatile bodies evolved during the fusion rise from the double decomposition which takes place in the melted matter, but at the above period these are not disengaged in such abundance as to generate an effervescence in the mass. In about four hours after the charging, the matters adhering to the sides of the furnace are struck into the bath, and the whole rabbled with an iron tool of this form. At this period the flux, or scoria, is very fluid, and in a very short time, when the heat is increased, the whole mass is in tranquil fusion. The entire operation is completed in about six hours after the charge has been introduced. The furnace-door is then opened, and the attendant, by means of a long rake, skims off the scoriæ or slag, as represented in the above figure; but generally the bed of scoriæ has partitions not shown in the figure, by which the slag is formed into pigs, or ingots, and these are removed and examined with greater facility than when in one mass. The tap-hole being now carefully opened, the very fluid matt, which at this stage has nearly attained to a white heat, flows out either into the cistern to be granulated, or it is conducted into channels in sand, where it is cast into pigs of about one hundredweight each.



The cupreous product, which approaches to the composition of pure sulphide of copper—Cu S—retains, for reasons already stated, a variable quantity of sulphide of iron, and the slags, or scoriæ, in like manner contain more or less copper. The latter are assorted and divided into two lots: the richer portion, or that which was in contact with the matt, and which contains most oxide of copper, is occasionally submitted to a special operation to recover the metal; but generally the whole is fused again with the calcined ore in the second process, where it contributes to the fusion of the materials.

In this operation the results may be stated thus:—

Blue metal,	0·402
Poor scoria,	0·261
Rich scoria,	0·281
Furnace waste,	0·009
Sulphurous acid,	0·043
Water and carbonic acid,	0·004
	1·000

The blue metal has generally a greyish-white color, but when it is cast into bars the appearance is bluish; when broken, it is found full of small cavities, and its texture is granulated. Its average composition is—

	Centesimally.
Copper,	73·0
Iron,	6·5
Sulphur,	20·5
	100·0

It sometimes happens that the quantity of copper does not exceed sixty per cent., but in this case the process has been badly managed, either in selecting the materials or in the fusion.

Fifth Operation.—The usual routine hitherto followed in the several processes, in dealing with the ore, is interrupted here, and the product of the fourth fusion is not used, but only other substances of a different nature and class; hence, to tabulate the course of procedure in the way in which the above order indicates, would appear contradictory and confusing; but it was customary in the copper foundries of Swansea, to adopt this plan of working fresh materials with the slags and various other matters containing copper, and to bring the valuable matter in them into a fit state to undergo the same operation as the product resulting from the last fusion, and which will be described under ninth stage. There is another purpose in view, and this is the production of a better quality of copper. Rich foreign ores and matt which are imported into Swansea from Chili, if mixed with the ordinary productions of Cornwall, would give a metal only of medium quality, having some good but many bad properties. It is the practice in these cases to work only the copper ores, which are free from the more difficultly eradicated impurities, and for this purpose these intermediate operations were added to recover the copper from the ore and the slags formed, in the state of white or blue metal. These operations were grouped together under the designation of the *extra process*, to distinguish them from the ordinary course, which would link the fourth and ninth operations together. Both are, however, intimately connected in more ways than one: for instance, the material used is identical with the product of the second fusion or coarse metal; this union is brought closer by the use of the richer slags from the last operation, which, when they have undergone another fusion, the resulting matt of white metal is submitted to the seventh and eighth fusion, as well as that derived from the extra product of the fusion under consideration, and the whole is treated in the ninth operation indiscriminately. Indeed, these several stages for enriching the matt, although they effect reactions more efficacious towards removing the substances which might deteriorate the copper than the fusion in the fourth one, still are nearly identical with the latter and with the ninth operation yet to be described. This is especially the case in regard to the fifth fusion, which is only a modification of the preceding one, and the roastings in number seven and eight are merely repetitions of the ninth method.

The material employed here is, as already stated, chiefly composed of calcined matt from the purer variety of ores; but, in general, a quantity of the ordinary substance resulting from second calcination is taken and incorporated with other materials in the annexed ratio :—

Calcined coarse metal from third operation,....	0·722
Calcined ore of the second or third class,......	0·185
Earthy matters—silica,....................	0·084
" bricks,....................	0·009
	1·000

The furnace in which the process is conducted is identical in form with that used for the last fusion; and the consumption of fuel is in this, as in the foregoing, composed of anthracite and caking coal. The time occupied in working the charge is about six to seven hours, making twenty-two charges per week. Like the substances used in the fourth operation, these undergo a gradual fusion, which, towards the close, becomes urged by a very high heat. Very little change is exerted till the matter becomes liquefied, when the oxide of copper reacts upon the sulphides of iron, giving rise to a sulphide of copper and an oxide of iron, which enters into combination with the silicious matter, and generates a very fusible scoria. Sulphurous and sulphuric acids are likewise liberated; but a portion of the sulphur is substituted for the oxygen derived from the oxide of copper, thus converting the whole of the latter into a sulphide. This constitutes the refining process, which is chiefly intended in this operation—namely, the removal of the iron and excess of sulphur, leaving the copper combined with the least quantity of the latter element. The weight of the charge is two tons; and the results after the fusion may be expressed as in the annexed table :—

Blue metal for the seventh operation, ...	0·495
Scoria for the second operation,..............	0·434
Furnace waste for the fourth operation,.......	0·008
Sulphurous acid, ...	0·056
Oxygen,.................................	0·007
	1·000

After the charge is worked off, the matter closing the tap-hole is completely removed, and the cupreous fluid permitted to flow out into moulds, which is called blue metal. The slag is then permitted to run out at the same orifice, exercising with it the same precautions as have been already stated in regard to operation fourth.

Sixth Operation.—In this stage, the slags resulting from the preceding and the two succeeding fusions, and which are rich in oxide of copper, as well as some rich sulphide of copper from certain ores, which, however, are free from injurious substances, are treated. The furnace in this case is slightly modified to suit the material which is being operated upon. No hopper is appended, in consequence of the substance being in too large pieces to conveniently pass through; but a charging door is formed in one side; and when the lumps of scoria are injected, very little exertion is required to spread them evenly over the sole of the furnace. During the succeeding treatment, this door is kept closed, and luted at the sides, so that no air can enter. When the matt is ready, it is drawn off, as usual, through an orifice for the purpose, made at the extremity of the transverse diameter of the hearth, opposite the side in which the charging takes place. The medium of heat is the same in this as in the other furnaces, and the time occupied in working extends to about five hours and a half. As the quantity of oxide of copper in the scoria employed cannot be wholly converted into sulphide of copper by the action of the sulphur combined with the iron in the ore added, it is reduced to the metallic state, and afterwards purified in the succeeding treatments.

This is brought about by adding to the substance slack, or ground coal, or charcoal; the results of this reaction are carbonic acid and metallic copper, which, owing to its greater gravity, penetrates the scoria and matt, and forms a layer of impure black copper, or *bottoms*, on the hearth. In this behavior the reduced metal effects an important part in purifying the matt of sulphide of copper; for it reduces and precipitates with it certain portions of tin and arsenic which are present, the removal of which would otherwise be difficult, and the presence of which would operate deleteriously upon the quality of the metal. The nickel and cobalt which sometimes exist in cupreous minerals are in like manner decomposed, and carried down in the black copper, their sulphur being transferred to a portion of the oxide of copper in the slag. Mr. VIVIAN has obtained a patent for the recovery of the cobalt and nickel from this body, as will be seen under the article COBALT, at page 490. A product of great value in copper of different states of purity, is the result of these various depurating reactions.

In the charge for this furnace, which amounts generally to two tons, the several substances are taken in the proportion of the annexed table, or thereabouts, *videlicet :—*

Rich slag from the fourth operation,..........	0·671
" " seventh "	0·095
" " eighth "	0·053
Copper pyrites,............................	0·079
Sweeping of the foundries from the eighth, ninth, and tenth operations,..................	0·055
Carbon, employed as reagent,.................	0·001
Earthy matters—sand,......................	0·036
" brick,......................	0·010
	1·000

Details of working are similar to those pursued in the fourth fusion, only that the hearth of the furnace is in this instance more liable to corrosion, because sulphurous products are in much less abundance, and the scoria and iron react upon it, abstracting the silica. Such is the case, especially in the parts adjoining the walls; but as a preventive, the charge is piled round on these parts, and as soon as the matter becomes molten, the quartz, which forms a considerable part of the ore added, supplies the silicious matter to the iron, and the hearth is preserved.

At the close of the process the fused matter is in three layers; the upper is constituted of the scoria, the middle of fused matt, and the lower of black copper; these are drawn off as usual.

The Editor is aware that the two last-described operations are now all but discontinued at Swansea, owing to the large import of Australian ores, which are mostly all rich carbonates producing pure copper. But as this publication may be taken as a guide for smelting operations in localities producing sulphides poor in copper or impure with other metals, and where rich ores of a pure sort cannot be found, he thinks it proper to detail these processes on account of their suitability for such unfavorable circumstances.

Seventh Operation.—Blue metal is here converted into white metal, or sponge regule, by the agency of the air; and the chief or entire part of the remaining iron is removed, by forming a fusible silicate toward the close of the roasting. The furnace which is requisite for this double purpose is constructed like that mentioned under the last stage, with charging-doors at the side and end, opposite the fire, and a tap-hole in the other side, at the end of the middle transverse diameter. In addition to these, air is admitted by openings near or through the bridge of the hearth, as already described in reference to operations of roasting. Crude blue metal constitutes the charge; but it carries with it a certain quantity of sand from the moulds wherein it was cast, and during the working more or less of the materials of the furnace are disintegrated and carried off in combination, partly with the iron of the scoria, so that the components of the charge may be represented in the relative proportion expressed in the annexed table, *videlicet*:—

Blue metal either from fourth or fifth operation,..	.0·789
Furnace waste, &c.—sand,	0·108
clay and brick,	0·006
Oxygen derived from the air,	0·097
	1·000

Two tons of the blue metal or sulphide are introduced carefully at the side and end doors above referred to, the temperature of the interior being somewhat reduced in order not to effect the fusion of the substance very readily. Care must likewise be taken that the bars of material are deposited within the furnace as perfect as possible, in order that they may present interstices for the flame and oxidizing current to pass through, which will thereby effect a better roasting than could be done were the charge in small fragments. As the blue metal is brittle, it is customary to employ a kind of tool not very unlike a baker's peel, and which is worked by four persons for introducing it. It is kept at some distance from the bridge of the fire, as near this it would meet little of the flame; for this reason, about two and a half to three or even four feet are reserved between the matter operated upon and the furnace bridge. The heat applied in this case is, during the first part of the operation, very moderate, but in proportion as the sulphur is eliminated, and the oxidation of the metals proceeds, it is increased, till in the end it is raised sufficiently to bring the charge into a fluid state. By this routine, the iron, which had only been oxidized during the roasting, is combined with the silica, and forms a fusible slag, which is carefully skimmed from the matt at short intervals, so as to expose a new surface. After twenty-four hours the metal is let out into sand beds for next operation.

The results of the charge are proportionally expressed in the annexed table:—

White metal for the eighth operation,	0·588
Poor slag for the second operation,	0·103
Rich slag for the sixth operation,	0·177
Furnace waste for the fourth operation,	0·008
Sulphurous acid,	0·124
	1·000

Eighth Operation.—This is only a repetition of the preceding treatment, and is conducted in the same manner. The charge weighs about two tons and a half, and the time of working extends over seven or eight hours.

Two stages are observed in this process: first, the roasting, or, in other words, keeping the mass in a semifluid state, by which a still further quantity of sulphur is expelled, and oxide of copper with sesquioxide of iron is produced; and, secondly, the fusion of the mass before being let out, which effects a reduction of some of the oxide of copper contained in the slag: when it comes in contact with the matt of rich white metal, it yields oxygen to the sulphur in combination, and gives rise to the formation of sulphurous acid and the precipitation of metallic copper.

White metal from the seventh division is usually employed alone, especially if a first quality of copper is to be produced; but when this is not the case, the matts procured from the first and sixth fusion are mixed with it in the ratio tabulated as under:—

White metal of the seventh operation,	0·712
White metal of the sixth operation,	0·125
Red metal of the sixth operation,	0·034
Earthy matters from the sole,	0·041
„ „ brick and clay,	0·007
Oxygen from the atmosphere,	0·081
	1·000

After the roasting is carried on with a gradual increase of temperature for about ten hours, this part of the work is considered to be thoroughly performed; the fire is then urged and the matter melted, and by this means a further quantity of sulphurous acid is liberated, in consequence of the action of the excess of oxide of copper in the slag upon the matt of sulphide of copper, by which the sulphur is oxidized, and a proportionate weight of metal precipitated. This precipitation of copper aids considerably in refining the matt of any portions of arsenic, tin, *et cetera*, which may be contained in it, and which it carries with it to the bottom. During the ten hours roasting, these changes are being instituted; and during the fusion, the scoriæ being repeatedly skimmed off, the charge after twelve hours is tapped out, and is found at the close separated into two distinct layers. Of these, the upper one consists of the pure matt or regulus; and the under one, of bottoms, or an alloy of copper and tin, with an admixture of more or less matt. Should there have been no tin or other metals in the ore, of course the bottoms will be pure copper.

Ninth Operation.—In the procedures of some metallurgists, this forms the fifth division of the work of copper smelting, and if the succession of treatments be considered in reference to the materials, it might be so distinguished; but to prevent a recurrence to matters already recounted, the entire course has been tabulated as successive stages. Nothing marketable, with the exception of the tin alloy obtained from the fusion of the slags in the sixth process, has hitherto been obtained; and all the work described in the preceding has been expended in bringing the metal into a suitable state for immediate reduction. To insure this, the sulphur in the ores acted as an important and the only suitable vehicle, whilst the auxiliary components, such as the silica, *et cetera*, maintained their utility in removing the most frequent concomitant of copper in ores, namely, iron. The work of these bodies, so far as is required in the generality of cases, is performed at the respective stages, two, four, five, six, and eight, although, as described, the product accruing from the fifth and sixth fusion is further treated in the two succeeding stages to provide a richer and better result. The apparent digression which, as detailed in the foregoing pages, is generally made for this purpose, is here omitted by converging into the usual routine the whole of the matters produced; for although the regulus of number *eight* might be worked alone, yet the treatment which it has to undergo is precisely the same as the matt from number *four*.

The object of the ninth operation is the expulsion of all the sulphur, and the obtaining of copper free from any metallic impurities. Both these results are arrived at by the agency of heat and the oxygen of the air upon the regulus and matt. When the furnace is brought up to its proper heat, all the air passages are opened so as to admit of a free current over the fused mass. In the treatment of the regulus here, the first change which is produced is the expulsion of the sulphur, by the direct action of the air and the influence of the oxide of copper upon the undecomposed sulphide; and the second is the removal of the iron, by the slag forming a liquid scoria with it. To secure this there are four divisions or steps strictly observed in the course of working: the first being the immediate roasting of the material; the second and third, two periods in the mutual decomposition of the oxide and sulphide of copper; and the fourth is the production of metallic copper and the removal of the slag which have formed during the last fusion.

The furnace wherein these changes are effected is like the foregoing, having a side and an end door, the latter for charging and working the fused mass, and the former for drawing out the molten matter at the termination of the process. From three to three and a half tons of matt, from the several operations already alluded to, are introduced in large masses at the end and side doors, and piled upon the floor of the reverberatory; afterwards, these orifices are closed and luted so that no air can enter, and the fire quickened. During the first few hours the calcination and fusion proceed at the same time, but in such a way as is very favorable to the elimination of the sulphur. The combustible gases striking against the pile of matter melt the surface, causing it to trickle to the bottom in drops or tears, by which it exposes a large surface to the current of oxidizing fluid, and, consequently, becomes deprived of its sulphur. This proceeds till the whole is in a fluid state, which usually happens in four hours after charging. At this stage the air can have little effect, but the liberation of sulphurous acid still goes on, in consequence of the mutual decomposition of the oxide and sulphide of copper, and which is such as to cause an effervescence of the mass, owing to the liberation of sulphurous acid gas.

In order that the double decomposition of the substances may be as complete as possible, the heat is now arrested, and the fluid mass left to itself for some time. This is done by opening the door of the fire, and only preserving the latter in such a state, that by closing the door the interior may again be quickly brought to its ordinary elevated temperature. The effect of the cold air passing over the molten material is to cause a crust on the surface, and the reduction of the heat from a bright to an incipient state of redness. As, however, the sheet of solid matter is a bad conductor of heat, the bulk of the substance is preserved at such a temperature as is favorable to the reduction of both compounds, but insufficient to bring about the union of the slag and metallic oxides. In a short time the coating becomes so tenacious and rigid that the sulphurous acid formed in the matt cannot escape freely, but collects in large cavities under it, causing an intumescence along with a commingling of the whole matter, which serve the purposes intended by rabbling much better than it could be executed by that means. This development of sulphurous acid continues during ten or twelve hours, at the end of which time the semi-metallic mass has considerably cooled, and gaseous bodies cease to be given off. When this happens, it is a sign that the reaction of the oxides and sulphides is complete, and that the third step must be taken towards completing the work. If the substance be examined at this stage it will be found extremely porous, owing to the retention of the sulphurous acid. The fire is now urged, the doors closed, and the furnace again brought to a brisk red heat, when a further separation of sulphurous products takes place during the melting. Six hours are occupied in this part of the process, and at their expiration the chief portion of the sulphur is driven off. All this time the oxides produced do not unite with any of the silicious matters, the temperature being insufficient to effect this change. It often occurs, from very impure ores and other causes in the working, that the matters put into this charge are what is termed coarse, that is, contain much sulphur and other impurities. When this occurs, considerable extra care and time are required to bring the charge into the proper state of purity for the next operation. The metal as it becomes reduced is seen as a bright oily liquid, which to the practised eye gives a good idea of the state of the charge. When the sulphur has been expelled as much as possible, the heat is raised to the highest point, it generally requires twenty-four hours for the complete working of the charge. The changes which the latter fusion determines are the union of the metallic oxides and the silica; but in this considerable quantities of oxide of copper, often as much as one-fifth of the whole weight, are carried off, as well chemically combined in the form of silicate of oxide of copper as mechanically mixed with the latter. Metallic particles are likewise discerned in the scoria, and these become so hard when cold as to be broken with difficulty. During the process, the scoria is skimmed off the bath of metal, and, after the last skimming, the tap-hole is opened, by which the metal flows out into rectangular moulds formed in the floor of the foundry. This is called *blistered copper*, on account of its numerous bubbles, similar to steel, formed by cementation.

The composition of blister copper is very constant, averaging from 93 to 96 per cent. of copper with a little sulphur and oxygen, the blisters being in all probability caused by the escape of one or other of these impurities as gas. The following may be considered a fair specimen of good blistered copper:—

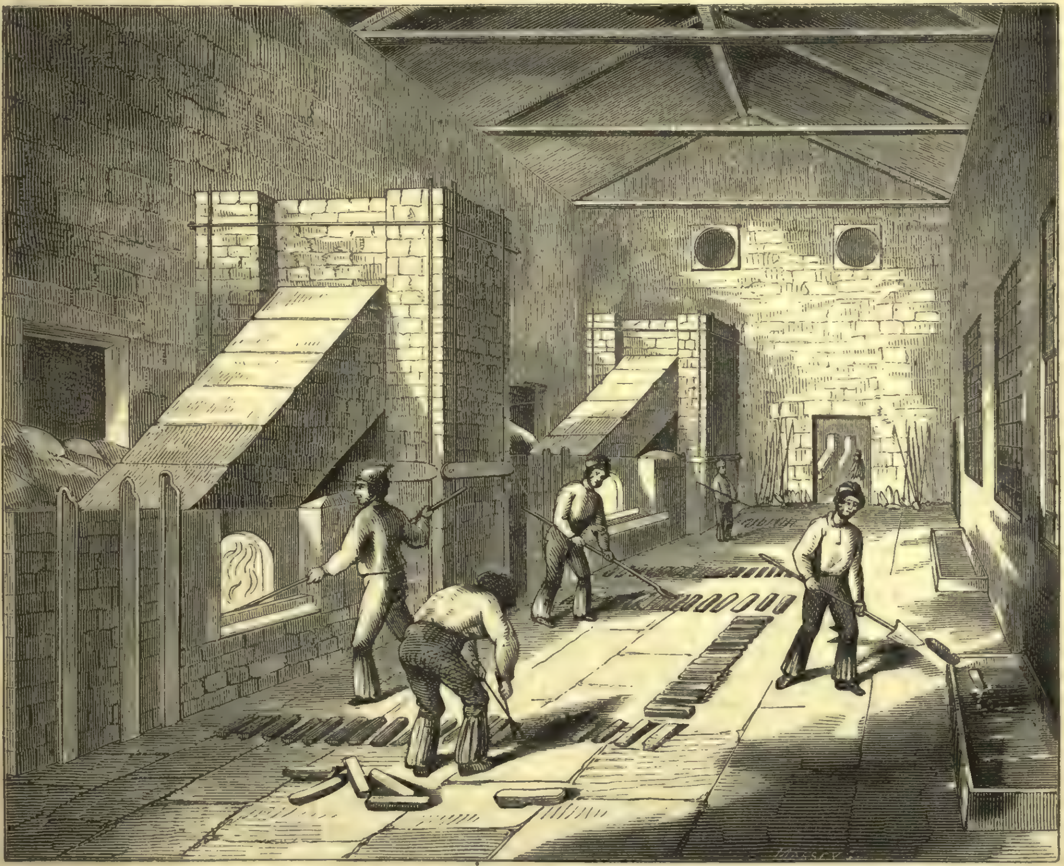
Copper,	95·60
Sulphur,	·69
Iron,	·28
Silica,	·12
Antimony,	trace.
Oxygen and loss,	3·31
	100·00

The resulting copper is brittle, the fracture exhibiting a deep red color, and numerous cavities in the interior.

It cannot be used in the arts, owing to the presence of the sulphur and other matters which destroy its tenacity, and which are removed effectually by the refining process, which here must be designated the

Tenth Operation.—In this the toughening and refining of the copper, so as to bring it to that state adapted for the mechanist, are performed by a method similar in some respects to the preceding operation.

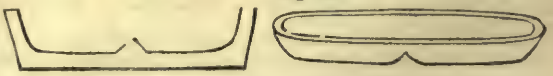
Fig. 325.



A charge of the pigs of blistered copper, weighing from six to ten tons, is introduced by means of a peel into a furnace of the same construction as that used in the last operation, only that the grate is larger on account of the increased consumption of fuel required to maintain the proper heat. No other body is employed in this operation to depurate the metal till the preliminary roasting is completed, only some adhering sand and part of the matter of the furnace which are subsequently thrown off as scoria. Care is taken in the introduction of the masses of metal, to place them so that the greatest amount of surface will be presented to the flame, and likewise that the draught may not be impeded. This being done the fire is attended to, and the heat sustained during the eighteen hours that the charge is left to roast. This is so managed that, in about six hours after the charging, the copper begins to melt freely, and the heat continuing to increase regularly, brings the whole, within the period of eighteen hours, to such a state as that the oxides of any foreign bodies, together with some oxide of copper, will have united with the silica. What remains of the iron, or any other metal, in the molten bath, unoxidized by the current of air passing through the furnace, is so oxidized by means of the oxide of copper, which is decomposed by them into metal and oxygen, the latter of which they appropriate. The high temperature is maintained during a further period of three and a half or four hours, which renders the bath of metal as free from impurities as is possible under the circumstances. The working door is now opened, and the bath is found covered with a layer of scoria which is raked off, leaving the metal ready to be *refined*. These scoriæ have a reddish color, a lamellated structure, are heavy, and, on the whole, resemble oxide of copper. Hitherto one man had the care of two furnaces, but now more men are employed in the refining, and the preceding part of the business is so regulated, that each furnace will be ready for the *refiner* at the usual working hour in the morning. At this stage the metal is brittle, of a deep red color, and coarse fracture; considerable quantities of oxygen are also interspersed through it, and which are to be expelled in the succeeding treatment; tenacity is also to be acquired, as well by removing the oxygen as by causing a different aggregation of the molecules of the metal. The first thing which the refiner has to learn is the state of the *dry* copper, as it is called, and this is done by taking out a sample with a small ladle and casting it in a mould; when cold this is broken, and from its appearance, together with the state of fusion and the intensity of the fire, he calculates the quantity of charcoal and spars of wood which will be requisite to communicate the suitable degree of toughness.

It has been stated, under the properties of copper, that it absorbs oxygen at high temperatures; were the bath of metal exposed to the current of air passing over it, after the covering of scoria has been removed, this would happen, and occasion be given for a larger consumption of charcoal, *et cetera*, than would otherwise be required. To prevent such a combination, some ground charcoal, or best anthracite coal, is scattered over the surface of the metal, which serves the purposes of excluding the air and deoxidizing any portions which may come in contact with it.

Fig. 326.



This constitutes the first step in the refining, but the action of the covering of charcoal thus used, cannot penetrate beyond the surface, and hence the oxygen in the interior remains unacted upon by it. To eradicate this element, it has been the practice, time out of mind, to agitate the fluid metal with a spar or pole of green wood, generally birch, and this continues at the present time to be the only method in use. One of these poles is thrust into the fluid bath, and the carbonaceous gases which it evolves effectually reduce, during their ascent through the fluid metal, any oxide of copper, being themselves converted into carbonic acid. These gases throw the metal into a violent commotion, which serves to bring every particle of it within the range of the deoxidizing agents. The ebullition of the metal by the action of the poles is continued from fifteen to about twenty-five minutes, or half an hour, the surface being still kept covered with fresh additions of charcoal. The period for arresting the poling is ascertained by taking samples from time to time, and testing their ductility and malleability in the vice and under the hammer. For this purpose the refiner has a small ingot mould attached to the end of an iron rod, and this he quickly dips into the spot at some distance within the door, from which he clears away the coal and scoria. When the sample solidifies, it is cut half through by a chisel or shears, and then repeatedly bent by blows from a hammer whilst it is held in the vice. By various trials, made in this way, of ingots taken from the charge, some of which are broken when cold, hammered on the anvil while red, or cut, the knowledge of the point when no more oxide of copper remains, and the grain of the metal becomes sufficiently fine, is arrived at with considerable precision. Long and diligent observations are required to be able to detect this point with certainty, because the several assays vary to some extent in every variety of copper according to their malleability; and so with the repeated samples taken from any particular species from the first to the last during the refining. When the poling has not been continued long enough, the ingot, when cut and broken, appears almost devoid of metallic lustre, but having a brick red color, and a fracture which is dull and granular. Upon continuing the action of the charcoal and the birch spars, in proportion as the required point is neared, each succeeding ingot shows an improvement in the grain, as also in the color of the metal, till finally the former assumes a beautiful silky lustre, and a fine pale red hue. When these characteristics appear, the refining is considered to be finished, and the assayer is particular to notify to the attendants to withdraw the spar of wood, and prepare for the casting. The fire which, from the commencement of the poling, was cut off from the metal by conducting the draught through another flue in the upper part is now revived; and after the coating of scoria, which resulted from the ebullition of the metal and the combustion of the fuel, has been raked off, and a few shovelsful of charcoal thrown upon its surface, the superior flue is closed, and the heat carried through the furnace as usual. In this way the metal is retained fluid, and the layer of charcoal takes up any oxygen which may pass over it, so that there is no possibility of oxidation. The men now proceed to cast the copper into moulds of suitable dimensions—such as are represented in Fig. 326—using on the occasion ladles which are coated with clay. This procedure is represented as conducted at the establishment of Messrs. Newton, Keates, and Company, at St. Helen's, in Fig. 325 on the preceding page. The utmost caution and expertness are required on the part of the refiner, apart from the knowledge which is indispensable, in order to judge of the relative purity of each sample as he draws it out, and which varies with every variety of metal; for if the poling be prolonged only a few minutes beyond the time at which the assay shows, from its silky grain and fine rose color, that the refining is completed, it would deteriorate the product considerably. Under such a condition the grain becomes coarser, and the lustre, though still retained, loses the silky appearance of the well-refined metal. Should the poling be still further continued, it will render the grain of the metal rougher, the fracture fibrous and striated, and the brittleness will be increased even more than when it was in the *dry* state, in consequence of the formation of a carbide of copper. When such an occurrence happens the coating of charcoal is skimmed, and the bath exposed to the air passing in through the fire and rushing in at the doors, which has the effect of bringing it back to its ductile state once more. In like manner, if the metal should not be kept covered with the charcoal during the casting, injury would arise from the absorption of oxygen, and the refining would, in the language of the operator, go back. When this is the case, recourse must be had again to the spars of wood to reduce any oxide that may have formed.

Sometimes considerable difficulty is experienced in bringing the copper to that state of purity necessary to insure its sale; and when other metals are present, the gas liberated from the spars of wood fails to have a beneficial effect. In this case it is better to add some lead, and to rabble the bath thoroughly for some time: this metal, while divesting the copper of oxygen, forms a medium through which the iron, arsenic, tin, *et cetera*, are converted into oxides, and thrown off as scoria, on account of its great affinity for oxygen. Care must be taken, however, that the agitation is protracted, so as to bring every particle of the lead within the influence of the air at the surface of the molten mass, where it is converted into litharge and removed by the rake. Should any of it remain in the copper, it would occasion a difficulty in the lamination, by preventing the scales from falling cleanly off the surface. The results of the charge operated upon, and represented as follows—

Coarse copper,	0·954
Earthy matters, sand,	0·013
,, ,, brick and clay,	0·021
Oxygen of the air,	0·012
	1·000

are given in the annexed form:—

Saleable copper,	0·908
Slag for operation four,	0·055
Furnace waste do. do.	0·022
Copper sweepings do. do.	0·002
Sulphurous acid,	0·013
	1·000

Hitherto only the usual routine of the large smelting works has been described, and this with reference also to the more commonly occurring ores containing copper and iron, or at most only traces of tin or silver, of which little notice has been taken in the foregoing pages. Although some portions of tin are obtained in the alloy resulting from the eighth operation, yet, if the amount of this metal in the cupreous mineral be at all appreciable, the quantity thus recovered bears but a very low ratio to the per centage in the ore, every means having been taken to oxidise it in the process, and draw it off in the slags. The silver, which sometimes exists in such minerals, would well pay the cost of extraction.

PATENTED IMPROVEMENTS.—Various patents have been lately granted for improved methods, whereby the smelting of the ores is expeditiously and economically performed, and also the valuable metals so frequently contained in them obtained. One of these, known as BRANKART'S, and which is said to be in active operation at the Red Jacket Copper Works in Neath, Glamorganshire, is especially adapted for the reduction of the rich South American and other foreign ores operated upon in this establishment, but it may be applied also to poorer kinds. The principle of the patent is the conversion of sulphide of copper into a sulphate, extracting this from the gangue with water, and precipitating the metal by iron, which is, during the operation, converted into sulphate or copperas. Considering that about the same weight of iron is required to effect the reduction as of the metal obtained, it would appear to the Editor that this would militate against its general use.

As is evident from the preceding remarks, the ores suited to such treatment are copper pyrites and rich sulphides; those supplied from the Cuban mines, and which are known as *Cobre ores*, generally contain from fifteen to twenty-five per cent. of metal, together with iron and other impurities. The course which the patentee recommends, is to reduce the substance to powder, and then expose it during several hours to the heat of a calcining furnace, by which considerable quantities of the sulphur are dissipated as sulphurous acid, whilst another portion is converted into sulphuric acid, which combines with the oxide of copper. When this process has been sufficiently prolonged, the ore is raked out and thrown at once into large vats filled with water. The sulphate of copper is dissolved, and after a short time the liquor is slowly allowed to flow out into another tank. The residue which remains on the bottom of the vat, and which still contains some metal, either as oxide or sulphide, is dried, and afterwards mixed with a proper quantity of the fresh ore and heated as before, when, by the reaction of the air, the sulphides and sesquioxides of iron, the sulphur will be converted into sulphuric acid; this unites with the oxide of copper, and forms a sulphate which may be washed out in the manner already indicated. When the proportion of sesquioxide of iron increases in the exhausted ore no copper is lost, for it causes the formation of so much sulphuric acid from the sulphur in the crude mineral as will combine with the whole of the copper that may be present. Quantities of iron are thrown into the liquor, and the metal precipitates in the course of a few days, after which the supernatant liquor is decanted, the precipitate washed well with water, then dried and submitted to a slight process of refining. The sulphate of iron may be obtained from the liquor by evaporation.

The method of RIVOT and PHILLIPS is not very different in principle from the foregoing. They, however, instead of oxidizing the combined element, expel it completely by roasting for a sufficiently long time at a suitable temperature; and when this happens, or, as it is said, the ore is roasted *dead*, bars of iron are introduced through apertures made for the purpose in the hearth. As soon as these come into contact with the heated material which, at this stage, consists principally of oxides and silicious matters, reduction of the oxide of copper ensues owing to the greater affinity of the iron for oxygen, especially in the presence of sand. The oxide of iron which is thus formed is contained in the slag, which is, subsequently, skimmed from the metallic bath, united with silica. This operation is most suitable for rich ores; but if they contain other metals which affect the quality of copper, they cannot undergo smelting in this way, as the arsenic, tin, *et cetera*, would remain in part with it, and render it unfit for general use. Were it not for this, and the destruction of a large quanity of iron, the process might be brought into requisition, as by it very fair metal could be obtained at one operation.

The patent process of NAPIER offers as yet the greatest advantages for general application. By this the work of smelting is considerably reduced, and a larger yield of copper obtained than by the ordinary method.

In smelting, the chief object is the separation of the silicious earthy impurities, the iron, and the sulphur usually associated with the copper; the quicker and more completely this is performed, the more beneficial will be the method of working, for not only is a saving in labor and fuel effected thereby, but the quality of the metal will be improved. In the method under consideration, it is directed that the ores from Cornwall, and such as are similar to them, as well as those imported, be calcined in an ordinary furnace. This product is next mixed with a quantity of rich Cobre ores, or other sulphides having a high per centage of metal, the proportion being inferred from their analysis, as well as from the fact that the iron and silica combine to form a clean fusible slag, and that the resulting matt should contain from thirty to fifty per cent. of copper. The mixture is now to be introduced into a reverberatory, and fused as when preparing *coarse metal* or *matt*, and when the fire has thoroughly effected the liquefaction of the constituents the scoria is raked. At this stage a quantity of soda ash—crude carbonate of soda—or salt cake—sulphate of soda—is introduced and rabbled with the mass. The alkaline salt undergoes decomposition and becomes a sulphide, which dissolves any arsenic, tin, or antimony that may be present, and carries them off in combination afterwards when the mass is treated with water. If salt cake be taken, it is necessary to mix it with charcoal to reduce the sulphuric acid more effectually, and bring it to the state of sulphide; the quantity used being twenty to thirty pounds to one hundredweight and a half of the soda salt, and this mixture serves for one ton of the matt. A very short time suffices for the decomposition of the sulphate, so as to cause it to react upon the impurities already noted. When this decomposition is considered to be finished, the furnace is tapped, and the mass cast into moulds of a rectangular or other suitable shape. As soon as these solidify, so as to bear removal, they are put into tanks filled with water, where they disintegrate into an impalpable powder. After some time the water is siphoned, or otherwise allowed to flow off, and the sediment washed to remove the soda compound, and with it the arsenic, tin, or antimony which it dissolved, if they were present.

The finely-divided residue is now dried, and submitted to heat in a calcining furnace till the last traces of sulphur are eliminated; this, owing to the minute state of division of the matt, is done in twenty-four or, at most, thirty hours. Having thus reduced all the copper to the state of oxide, the latter is now to be mixed with a quantity of fresh mineral which is free from sulphur and arsenic, but rich in silica, and with coal or charcoal, and the compound treated in a smelting furnace in the ordinary way; reduction will take place, and a slag will be formed which will not retain much either of the metal or of its oxide. The purity of the metal thus obtained, which requires only about one-half the labor expended in the smelting on the old principle, is such as to command a ready sale.

When carbonates or oxides of copper, containing very little metallic bases and a large amount of silica, are treated, it is directed that iron scales from the rolling mill or hammer be added, in order to form a fusible scoria, and allow the deposition of the metal. About two and a half to four hundredweight of this material will suffice for working every charge, however refractory the ore may be; but with such ores they are mixed with the necessary flux and carbonaceous matters, and fused without any previous operation, when the metal is obtained in one operation ready for refining.

As there are few carbonates or oxide ores that are entirely free of sulphur, when this substance exists in the ore it remains with the copper after fusion. When this is the case, the copper obtained has to undergo from ten to fourteen hours' roasting previous to refining; and this is judged of by the practical man, from the appearance the copper has when tapped from the furnace.

Many other improvements have been announced of late years, to which only a short reference can be made. DAVIES, in a patent sealed in 1848, directs that when oxides and carbonates of copper, containing no other metallic impurities than iron or manganese, are to be smelted, they are to be so mixed that the silica of the ores may be to these impurities in the ratio of five to seven, either by adding one or other, as they are shown to be absent, by a rough analysis. If silica be in excess, peroxide of manganese is added; and should the latter or iron be predominant, silica is to be mixed with it in order to bring about the above proportion. Coal is afterwards added in sufficient quantities, and the whole fused in a smelting furnace to procure the metal. BIRKMYRE burns the copper pyrites so as to recover all the sulphur in the state of oil of vitriol and sulphates of iron and soda. The mineral is finely ground, then placed upon trays, which are sufficiently capacious to hold about one and a half hundredweight of it, and these are introduced into kilns similar to those in common use for burning pyrites.

Before submitting the ore to the heat of the kilns, it is mixed with a quantity of nitrate of soda, in order that the sulphur may be converted into sulphuric acid during the combustion. Whilst the ore is exposed to the heat in the trays, it should be repeatedly stirred with a rake, in order to bring every particle of it within the influence of the air passing through the furnace, that the oxidation may be complete. After an hour's calcination the trays may be withdrawn and their contents cast into water, where the sulphates of copper and soda produced during the foregoing part of the operation are washed out, leaving the gangue in the bottom of the tank.

The copper in this, as in NAPIER'S process, is entirely freed from arsenic, which is expelled in the form of arsenious acid during the roasting. The metal is recovered from the saline solution by precipitating it with iron.

DE SUSSEX directs that the ores should be so mixed as to have about sixty per cent. of silica present before they are submitted to the furnace. Should this body, however, constitute more than the per centage here mentioned, fluor spar, lime, or other substances, must be employed, which will form fusible or volatile combinations with it. To every five hundredweight of the ore, about twenty-five pounds of finely-burned charcoal or coal, free from sulphur, are added, and the whole introduced into a reverberatory in quantities sufficient to form a charge. During the three or four hours that it is exposed here to the heat, most of the sulphur will be expelled; but, to free it from the last traces, it is directed that the temperature be lowered by cutting off the draught, and about five per cent. of alumina, magnesia, magnesian limestone, or nitrates of potassa, soda, or lime, are to be intimately mixed with it in the furnace.

Preference is given to the first three bodies, but the others answer all the purposes very well. The heat is renewed and the charge roasted for some time, for the purpose of decomposing any sulphate of copper which might be produced in the foregoing part of the calcination, the acid of which is first transferred to the substance added, and subsequently expelled from it by the heat. It could be separated also by raking out the ore after the first part of the roasting is finished, and steeping it in a tank holding a solution of ammonia; sulphate of the alkali is formed, and oxide of copper precipitated. It is necessary, however, that the ammonia be not present in excess, for it would dissolve the oxide and carry it off in solution, causing the liquor to appear blue. The sulphate of ammonia can be again decomposed, and the alkali retrieved for further use by mixing milk of lime with the liquor; sulphate of lime is formed, and a solution of ammonia, which can be decanted or siphoned off for use when the precipitate has subsided. To procure the copper, the ore is taken out of the tank, dried, and mixed with an equal weight of anthracite coal, and four parts of silicate of potassa or soda, for every ten parts of silica in the substance, then melted in a furnace till the whole is fused in the usual manner.

Mr. CHARLES LOW, by a process patented in 1847, proposes to simplify the labor of smelting by employing a combination of peroxide of manganese, plumbago, nitrates of potassa, soda, or lime, and charcoal, as a flux. The proportion in which these are blended with each other is as follows:—

42	parts of	peroxide of manganese.
8	,,	plumbago.
2	,,	nitrate of potassa, soda, or lime.
14	,,	wood charcoal or anthracite.

When the fusion for matt is going on, a quantity of this flux is to be added and mixed intimately by rabbling, in order to cause the separation of the silicious and metallic impurities as scoria, and also to render this more fluid than it is on ordinary occasions, that it may be less fitted to retain any of the matt or metal. Twenty-five pounds are first used; and when the fluid slag rises to the surface it is skimmed, and the above weight of the flux again rabbled with the molten mass, and the scoria which it produces separated as before, and so on till the workman judges that the metal has arrived at a sufficiently forward state to run it off, and submit it to reduction in the melting furnace.

PARKES claims the use of iron or zinc at certain stages in the manufacture of copper, by which a better quality of metal is obtained from ordinary ores, than when such are treated in the common way. His method is to roast the mineral till a matt is formed, such as is known as *close regule*, to which the iron, whether wrought or cast, is added in the ratio of one hundredweight to each charge of two tons and a half of the above compound, and the heat of the furnace urged so that the substance may be kept for some time in perfect fusion, and after this it is tapped out as *pimpled copper*, and submitted to the usual routine of reduction. Sometimes the matt, after the introduction of the iron, may be drawn off as *light regule*, and the pigs or casts afterwards stripped, as in the manufacture of best selected. In this case, the portion thus stripped is again put into a furnace, and to every charge of the above weight about half a hundredweight of iron is added, and the heat continued till it becomes pimpled copper. This metal may likewise be used in refining, to remove oxygen from the copper, but only one hundredweight is proportioned to five tons of the latter; and the manner of working the charge is by agitation, so that the whole of the iron may be oxidized and thrown off as slag before the poling commences. When, however, it has been used with the matt, it is not afterwards needed in the refining. The Editor fears that great injury would arise to the furnaces by the use of this reagent, in consequence of the affinity of its oxide for silica. Zinc may be employed for the same purposes as iron, and the like precautions must be observed regarding it.

In the specification of TRUEMAN and CAMERON the following course is recommended. When sulphide of copper, or substances containing sulphur, are to be operated upon, the patentees roast them in the common way to procure a matt of coarse metal, which is afterwards ground, and a portion submitted to analysis, to ascertain whether tin, arsenic, or antimony is present. If these be detected, the powdered matt is boiled with a solution of caustic potassa for six hours, keeping the contents of the vessel well stirred during that time. The object of this is to remove those metals in the form of salts, namely, as stannate, arsenite, and antimonite of potassa. After the solution is drawn off, the residuary matter is calcined to remove all, or as much as possible of the sulphur, and produce an oxide, which is subsequently mixed with sulphide of copper, in such a proportion that the oxygen in the oxide will be sufficient to form sulphurous acid with the sulphur in the crude ore. It is likewise necessary that the silica in the mixture should correspond with the iron, so as to yield a fusible slag; if, however, enough of this body is not present to take up all the latter, then a certain weight of sand, or, preferably, the bottoms of old furnaces, called *cobbing*, must be mixed with it. The components of a charge which affords the metal with facility are thus stated, namely:—

26 parts of calcined powder, having forty-seven per cent. of oxide of copper.		
12 parts of Cobre ores, containing centesimally, ...	copper,....	26
	iron,......	26
	silica,......	16
	sulphur, ...	32
12 parts of cobbing, ...	silica,......	72
	copper,....	12
	iron,......	6

About two and a half tons of this mixture are submitted to the furnace and fused; five hours after the charging the whole is rabbled, then allowed to rest, and the slags skimmed as they rise to the surface; the fluid matt is not drawn off as usual, but another charge is introduced and worked like the preceding, after which the furnace is tapped. A rich compound of copper and sulphur free from iron, or nearly so, is separated, and when calcined and fused in the reducing furnace it yields metal of good quality. When the ores are mixed, so as to avoid the use of cobbing, the quantities taken are,—

22 parts of the calcined powder.			
10 ,, Cobre ores of the composition already given.			
18 ,, Burra-Burra ore, composed of	copper,	16	per cent.
	iron,	6	,, ,,
	silica,	58	,, ,,

Another mixture is—

25 parts of the calcined ore, and			
25 ,, sulphurous ore, containing centesimally, ...	copper,	10	per cent.
	iron,	18	,, ,,
	sulphur,	55	,, ,,

These several mixtures are roasted, as directed in the preceding, and the furnace tapped at every second charge; the matt is submitted to the reduction process already described. In a second patent, granted to Mr. Trueman in 1852, it is stated that the mineral—after calcination if it be sulphurous, but at once if only oxides and carbonates are present—is to be treated with an acid, to dissolve the oxide of copper, and after filtering is to be precipitated by means of chloride of calcium and lime, the following being the method of operation:—A number of tanks, marked in succession one, two, and so on, are provided; into the first of these a quantity of the powdered ore, together with as much sulphuric, hydrochloric, or nitric acid as will combine with the whole of the metal, is introduced, and the mixture agitated. When all the soluble matter is taken up, the solution is drawn over to the next tank, there to undergo a further treatment. When sulphuric or nitric acid is employed, the liquors will contain sulphate or nitrate of copper, and similar salts of silver, should any of it be present in the original substance. Hydrochloric acid or chloride of sodium dissolved in water is here added, in order to separate the silver as chloride, and when it has subsided the liquor is filtered or siphoned into the next vessel. Here it undergoes a peculiar treatment, according to the acid employed; if sulphuric acid had been the original solvent, chloride of calcium is added to it; double decomposition here takes place, producing a chloride of copper and a precipitate of sulphate of lime, the former being drawn off into the third tank after the subsidence of the latter. Milk of lime is now agitated with the cupreous liquid, when the hydrated oxide of the metal precipitates, and a chloride of calcium is produced. The solid substance having settled to the bottom, the liquor is drawn off, and water added to the residue to remove all the lime salt. Should nitric acid be used, lime salts cannot be employed, as the nitrate of lime is very soluble; in this case, alkalies must be applied to throw down the oxide of copper, and the nitrate which is formed may be recovered by evaporating the liquor to the crystallizing point after the separation of the metallic oxide by filtration.

By the action of hydrochloric acid only the copper is dissolved, the silver, if there be any, being left in the residue. The treatment of the chloride of copper is similar to that given for the solution of the sulphate, only that nothing further is required than to add milk of lime at once to precipitate the oxide. Hyposulphite of lime, or a hot solution of common salt, may be employed to divest the silicious matter in the first tank of the silver, and it can be precipitated from these menstrua afterwards by using hydrochloric acid if the first has been taken, and if the second, a large addition of water; by either treatment chloride of silver results.

The oxide of copper is easily reduced by mixing it with charcoal in a smelting furnace, and heating the whole in the ordinary way. If tin be contained in the ore, the patentee directs that, after the separation of the copper and silver, the gangue should be boiled with potassa for some time, by which the metal is dissolved in the form of stannate of potassa, from which it can be afterwards reduced; or the gangue may at once be submitted to fusion in the common way to recover the tin.

It will be well to mention here, that of late years the alkali manufacturers prefer to buy the pyrites they use for making their sulphuric acid, containing a small per centage of silver. Such ores are sold in the county of Wicklow at the following prices:—Silver smalls—as they are termed—containing four ounces of silver in the ton, at fifteen shillings; five ounces, sixteen shillings and sixpence; six ounces, eighteen shillings; seven ounces, nineteen shillings and ninepence; eight ounces, twenty-one shillings and ninepence; nine ounces, twenty-four shillings; and all above one per cent. at the Swansea valuation. The pyrites, after being removed from the kilns, are smelted into a regulus, which is sold to Messrs. Vivian and others, who extract the silver by a patent process.

Foreign Modes of Smelting.—Hitherto the smelting of copper pyrites and other sulphurous ores of this metal has been considered, especially in reference to the course adopted in England and Wales. In these countries the sulphides are more generally met with, and when limited quantities of non-sulphurous minerals of copper come into the market, they are treated along with the ordinary material at different stages of the work, as indicated in the foregoing pages. In other countries, however, where the minerals differ from those of Cornwall and other districts, a contrary course is pursued in the smelting. On the Continent of Europe many ores are found besides the sulphides of copper; such are oxide and suboxide, known as *red* or *black* ore, and the carbonate or *azure* ore. These require a special mode of working, distinct from the routine described. It often occurs that the cupreous body is mixed with carbonaceous matters, forming a kind of shale. Such is the case at Mansfeld in Germany, where the sulphide of copper is found disseminated through the shale in small crystals, being formed, doubtless, from sulphate of copper, by the action of the carbonaceous matter which has divested the former of all oxygen, and reduced it to the state of sulphide. The ores of Chessy, near Lyons, in France, are the azure and red variety, the former not discovered there till 1812, and the latter in 1825.

The annexed analyses of the rich and poor class of *red* ore of this locality shows that their smelting is not a very difficult procedure:—

	Centesimally represented.		
	Rich.		Poor.
Suboxide of copper,	86	..	45
Sesquioxide of iron,	4	..	20
Aluminous and silicious matters,	5	..	30
Water,	4	..	5
Loss,	1	..	0
	100		100

The composition of the *blue* ores likewise shows that they are capable of yielding a good return, and can be worked with comparative facility:—

	Centesimally represented.						
	Rich ore after picking and washing.		Rich ore after sifting.		Poor ore after washing.		Poor ore after sifting.
Protoxide of copper,	45	..	42	..	30	..	25
Oxide of iron,	1	..	4	..	2	..	5
Aluminous and silicious matters,	30	..	30	..	52	..	55
Carbonic acid and water,	23	..	22	..	15	..	14
Loss,	1	..	2	..	1	..	1
	100		100		100		100

These minerals are smelted at once in a furnace, called by the French *fourneau à manche*, shown in the annexed Figs. 327 and 328.

The first of these is a horizontal section on a level with the tuyere, or pipe, which directs the blast, and the second an elevation. The base of the furnace, A A, is constructed of solid masonry, strengthened by transverse bars of iron. B B, is a coating of refractory material, which is renewed at every season; it is cemented to the masonry in the form of an ellipse, its capacity augmenting to a certain point, as shown in the dotted line. The two lateral faces are formed of gneiss, and the front one, called *fiervende*, is constructed of rectangular iron plates, coated with fire-clay; these are supposed to be taken off in the figure. C C shows the form of the coating at the time of the firing; it is a rectangular parallelopiped of about six feet in length, five and a quarter in breadth, and about three feet and a quarter in depth. D is the sole, composed of firebrick made from Bourgogne clay and pulverized quartz. E is the tuyere, the muzzle of which is of wrought, and the bed of plate iron; its orifice is three inches in diameter. F is the platform or table, constructed of clay firmly beaten between the fore part of the furnace and three small walls which are bound by iron bars. Three steps are made in front for the convenience of the ascent of the workmen. G is a basin or crucible dug in the table in the front of the fire; it is made on a level with the sole of the furnace. It is coated with a mixture of clay and finely powdered charcoal, which preserves it from injury for weeks together. It is an inclined canal, opening into the recipient, I, where the fluid collects.

Fig. 327.

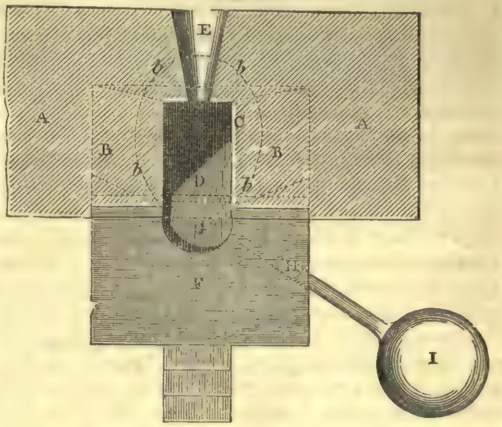
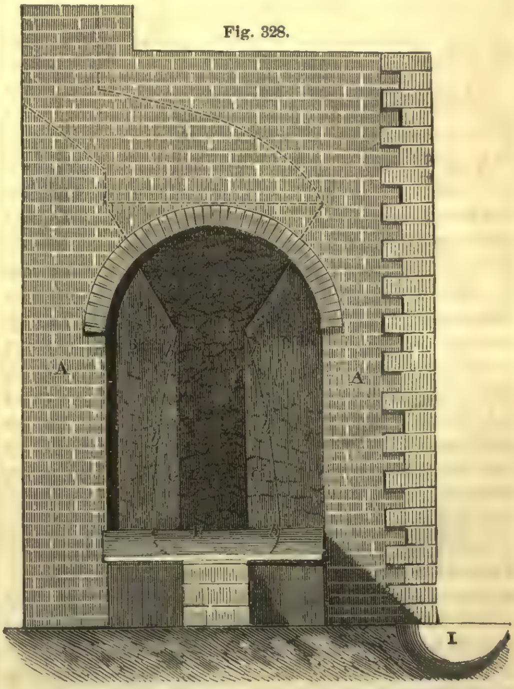


Fig. 328.



The ore to be smelted in this furnace is mixed so that the mean content of metal will be about twenty-seven per cent.; to this five per cent. of caustic lime are added, together with a small amount of scoria. Two hundred pounds of this mixture, mingled with about one hundred and fifty pounds of coke, are introduced into the furnace hourly, when the latter is in good working order. As the fusion and reduction proceed, the melted metal and scoria flow out into the bath opposite the fire, from which the latter may be separated by skimming it off. In about twelve hours the basin opposite the fire is filled with metal, which may be run off in the ordinary way into the recipient, I. Any scoria which might be carried over, floats on the surface, and can be easily removed. A little water is next sprinkled upon the metal; its evaporation causes the formation of a solid crust, which is taken out of the bath by a circular implement. By continuing this operation, the whole contents may be converted into cakes or discs of three quarters to one inch in thickness. The running takes place twice each day, and on the whole there is about thirteen hundred and three quarters of metal. It is necessary to repair the basin opposite the fire once a week. The products of the foregoing fusion are the ordinary slags formed in the furnace and those produced in the recipient, the black copper and other matters being carried off in the flue. The scoria is of three kinds, the blue, the black, and the red, but some of these retain only very small quantities of copper, as seen in the annexed table:—

	Centesimally represented.		
	Blue Scoria.	Black Scoria.	Red Scoria.
Silica,..............	55·0	56·0	58·6
Alumina,...........	7·0	9·0	5·0
Lime,..............	24·6	27·0	16·0
Protoxide of iron,....	11·9	7·0	12·6
Protoxide of copper,..	0·5	0·7	0·0
Suboxide of copper,...	0·0	0·0	6·6
Loss,..............	1·0	0·3	1·2
	100·0	100·0	100·0

The blue slags contain very little oxide of copper; they are formed when lime is present in sufficient quantity. Black slags are produced when the above earth is wanting, and the iron of the ore vitrifies the silicic acid of the mixture; they have more copper than the blue variety, and are often coated with a red scoria, which is indicative of the combination of oxide of copper with silica. Black scoria always tends to give rise to this compound, and hence care should be taken to have the necessary amount of lime present to hinder its formation. Red scoria is composed of silicate of iron and copper, and is evidently the result of not having the sand, quartz, *et cetera*, proportioned to such bases as would take it up and wholly prevent its union with copper; this, however, is not the only cause, for the same result follows the application of a high temperature in the furnace. Hence it is necessary to determine when the charge has its full dose of scoria, so as to effect the reduction of any red scoria which may arise, together with taking up all the extraneous matters in the ores; and likewise when the charcoal or fuel reacts upon them, so as to cause the reduction of the suboxide of copper which they contain, thereby transforming them to the blue variety. When lime is added in sufficient quantity, these are converted, without any other assistance, into black slag. The formation of these slags, rich in copper at the beginning, and flowing into the receptacle in front, is a sure sign that the heat of the furnace is too elevated, which causes them to run so quickly that the copper cannot be sufficiently reduced.

It may be conceived, likewise, upon similar grounds, why minerals which are very rich, are more difficultly treated than when they afford a large amount of slag; because the time necessary to effect the fusion in the latter instance is sufficient to reduce the metal completely, and hence, when the fused mass runs out into the crucible, scarcely any red slag is found in it. A proper amount of fluxing material always keeps the scoria free from copper, and any derangement in the working may be readily rectified by altering the mixtures operated upon, or diminishing the blast.

The composition of the scoria thrown off from the metal, after it flows over to the recipient, is—

	Centesimally.
Silica,..............................	30·5
Protoxide of iron,.....................	55·5
Sulphur,.............................	2·3
Iron,................................	1·8
Copper,..............................	4·4
Sand,................................	0·5
Loss,................................	5·0
	100·0

These scoriæ differ from the foregoing in not containing lime. The action of the air upon the bath of metal oxidizes a large quantity of the iron as well as some copper, and these reacting upon the silicious coating of the crucible, occasion its formation.

The black copper which results from these operations is of very variable composition. When the scoria is black, the metal is found charged with iron to the extent of seven or eight per cent. Even in the same running much difference may be observed in this respect, for the copper being denser than the metals accompanying it, settles to the bottom in large quantities, and hence the last cakes are richer than the first. The annexed is the mean of several analyses by M. MARGERIN of black copper obtained by the preceding method:—

	Centesimally represented.
Copper,..............................	89·30
Iron,................................	6·50
Protoxide of iron,.....................	2·40
Silica,..............................	1·30
Sulphur,.............................	0·34
Loss,................................	0·16
	100·00

The kinds of ores here alluded to might be worked with advantage in a reverberatory furnace heated with coal, mixing therewith some powdered charcoal, sufficient lime, and a little scoria to facilitate the fusion. The copper would thus be obtained entirely or nearly free from iron and sulphur.

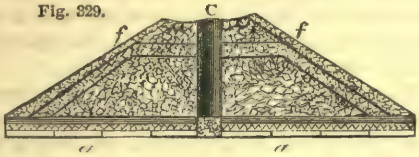
During several years an ore called *black mine* has been obtained from Chessy, near Lyons, in France, composed, according to THIBAUD and BERTHIER, of—

	Centesimally.		
	Rich Mineral.		Another sample.
Protoxide of copper,	12·00	14·0	12·67
Copper pyrites,.....	56·35	46·1	20·15
Iron pyrites,........	25·01	36·3	8·94
Sulphate of baryta,...	2·60	0·0	28·80
Sesquioxide of iron,	0·00	3·0	9·22
Loss,..............	4·04	0·6	Sand, &c., 20·22
	100·00	100·0	100·00

It is smelted in a furnace similar to that last described, without any previous preparation, only that half of the scoria from a foregoing charge, together with half from the smelting of carbonated ores, which are rich in lime and alumina, is added, to render it more fusible. In this way a matt is obtained which is afterwards submitted to five or six calcinations, in the same manner as described under the general procedure followed at Swansea and other places; and the decomposition of the sulphur compounds by the oxides is effected here in the way already explained. The sulphate of baryta is decomposed by the coal used into sulphide of barium, which, reacting upon the oxide of iron, gives rise to sulphide of this metal and baryta, which combines with the silica, and passes off in the scoria. An excess of heavy spar, however, is not desirable, as it occasions the presence of too large a quantity of sulphide of iron in the matt, which must be expelled afterwards at the cost of time and labor.

The cupreous schistose ores of Mansfeld, in Germany, after they have undergone a calcination, are smelted in cupolas, like those used in iron-works. They are not rich in copper, yielding only from two to three per cent., but they contain considerable quantities of bituminous matters, which contribute to the reduction of the metal. The first operation to which recourse is had, is the roasting of the ore in mounds, similarly to the manner of calcining alum shale, as stated at page 160, about a hundred tons being in each mound. They continue burning, according to the state of the weather, from fifteen to twenty weeks, chiefly at the expense of the combustible materials in the mineral. During this period the carbonaceous matters are consumed, the sulphur expelled as sulphurous acid, and the metals, to a large extent, more especially the iron, are converted into oxides. During this operation the ore loses about one-tenth of its weight, it becomes friable, and acquires a yellowish-grey color.

Fig. 329.



On the Lower Hartz, where copper minerals abound, and where there is iron pyrites containing about five and a half per cent. of metallic copper, together with more or less antimony and arsenic, the method of procedure is such that some of the sulphur is recovered during the preliminary calcination to which the ore is submitted. The manner in which this is performed is shown in Fig. 329, which represents a vertical section of a mound in the state of calcination. The form is that of a truncated quadrangular pyramid, the base of which is composed of wooden billets, *a a*, laid in such a way as to allow an access to the central wooden chimney, C. At the base of the latter, some charcoal is kindled, and the heat penetrating the pyritous mass, *d d*, suffices to effect a decomposition by which a portion of the sulphur is expelled as sulphurous acid, and another quantity as free sulphur, which is condensed in the upper part of the mound. It requires careful attention for two or three days, in order that the fire may take hold; when this is done, the mound is coated exteriorly with small and refuse mineral, as shown at *f f*, so as to direct the draught to the top. By the combustion of the wood on which the mineral rests, the latter is ignited; and the heat developed by the conversion of one portion of the sulphur into sulphuric acid. is sufficient to maintain the whole in a state of ignition. A number of cavities are made in the top of the mound, into which, as the upper portion becomes surcharged with sulphur, it collects in a fluid state, and is thence removed by an iron ladle, and cast into water to be further purified. After the first calcination the mound is turned over, and such parts as had agglomerated, subjected to a repetition of the preceding process, and when thoroughly calcined, mixed with argillaceous schist, and fused in the *fourneaux à manche* already described.

In the same manner, the Mansfeld mineral being calcined is next mixed with such ingredients as will promote its fusion, and then introduced into the furnace to be smelted. This mixture consists of relative weights of the schist, according to its composition, which is very variable, fluor spar, scoria rich in copper, and other refuse. Thus,

20	hundredweight of	ferruginous slate,
14	,,	calcareous slate,
6	,,	argillaceous slate,
3	,,	fluor spar,
3	,,	rich slags,

constitute an ordinary charge, which are put into the furnace with a proper quantity of fuel, generally coke, and smelted. In about fifteen hours this is worked off, and yields about one-tenth of its weight of copper matt, containing from thirty to forty per cent. of metal, the remainder being slag, which frequently retains considerable quantities of copper. Fig. 330 represents an elevation, Fig. 331 a vertical section, and Fig. 332 the base of the furnace used on this occasion; the last showing the outlets into the crucibles which receive the matt.

Fig. 330.

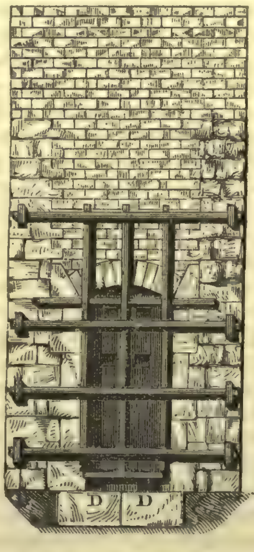
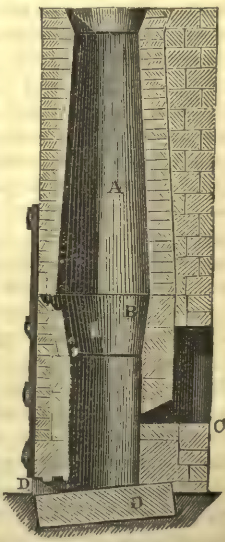
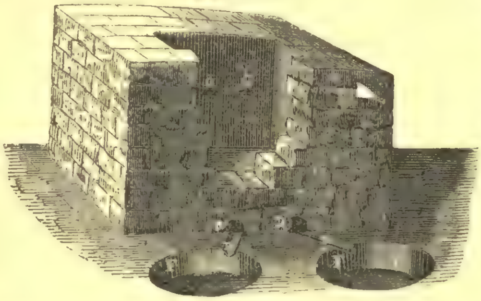


Fig. 331.



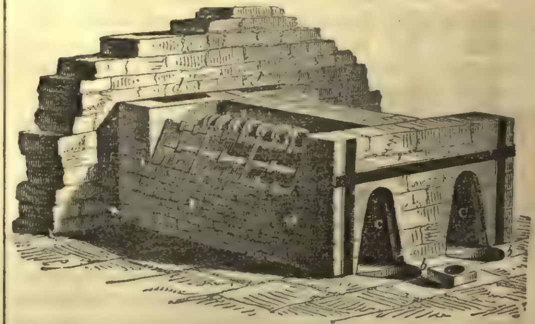
Here A represents the shaft, B the rest, C the tuyere, D the apertures through which the fluid flows by the channels, E E, into the basins, F F—Fig. 332. The shaft is constructed of firebrick, lined at the back with some refractory and non-conducting material, generally rubbish stones, and the parts adjoining the *tuyeres* of pudding-stone, through which the heat passes very slowly. The hearth-stone, G, is inclined to the openings, D, to facilitate the effusion of the matt into the basins. Generally, the height of this furnace is from fifteen to eighteen feet; the breadth at the tuyeres, which are two feet from the sole, about twenty-six inches, and at the widest part three feet and a quarter ; the whole is surmounted by a chimney of forty or fifty feet high, which conducts the gases out of the reach of the workmen. During the melting of the charge, the outlets, D, are opened alternately as each basin is filled with the molten mass. From these receptacles the matt is removed in the form of circular plates, which are lifted off when sufficiently cool from the surface of the still liquid sulphides remaining in the bottom of the cavity.

Fig. 332.



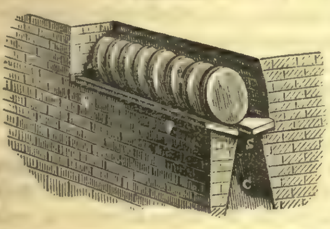
As the ores generally contain silver, zinc, and iron, with more or less of nickel and cobalt, some quantity of these, in the state of sulphides, is also contained in them. Whether this matt is subjected to one or other of two processes, is dependent upon the quantity of metal it may contain. In one it is roasted five or six times, and then smelted into black copper. When the matt contains only from twenty to thirty per cent. of metal, it is subjected to a routine of processes, by which it is concentrated before smelting for the reduction of the metal. The cakes are alternated with brushwood, and roasted three successive times in kilns, the product being turned over after each calcination; the charge in this instance weighs about three tons, and the operation extends over four weeks. This product is next fused in the cupola, with an addition of the richest slag from the first smelting as a flux. By this means a matt containing from fifty to sixty per cent. of metal is obtained. This rich product, called *spurstein*, is mixed with a certain quantity of the material from the first smelting, and roasted six consecutive times during a period of seven or eight weeks. Brushwood and charcoal are interlaid with the matter in this as in the previous roasting, and air is conveyed to the lower part of the mass, to maintain the combustion, by channels made in the walls of the compartments where the process is carried on ; these open inwardly at the bottom. The front wall of the kiln is composed of stone, built loosely, and with the view of keeping the charge in one compartment from intermixing with that in the opposite. When the matt has been calcined in the first of these apartments, it is transferred to the next, and there again interstratified with wood and charcoal as before ; when the roasting is effected here, it is thrown into the third, and so on in rotation till it comes to the sixth, where the calcination is finished. The resulting product is called *gahrrost* by the Germans ; it resembles in color red copper ore, but sometimes it has a bluish-grey shade ; it is brittle, and contains some of the copper reduced, and also more or less sulphate of copper, arising from the oxidation of the sulphur by the oxides. It is necessary to remove this by lixiviation, an operation which is carried on in a series of vats fixed in an incline, so that the liquor in the upper one flows into each in succession till it comes to the lowermost, and during its passage takes up as much of the salt as will make the solution so concentrated as to require very little evaporation to crystallize it. This washing is sometimes carried on after each roasting, and the sulphate of copper formed in each compartment extracted. Finally, the calcined matt is melted in the cupola furnace with about a quarter of its weight of the lixiviated matt from the first fusion ; when this is of a good quality, one-sixth to one-tenth of its weight of rich copper slags, and a due admixture of charcoal or coke, the charge varies from three to four tons, and the period of smelting extends over twenty-four hours. This operation yields black copper, and a slag of various degrees of richness ; but the former, being the heavier, sinks to the bottom of the crucible, from which it is removed in discs, as already described. The slag is subsequently roasted with other matt, and then smelted to divest it of the metal. The black copper usually contains an appreciable amount of silver, which is extracted by the process of eliquation, and occasionally the *gahrrost* is amalgamated with mercury to effect the separation. The principle of the first operation is, that when copper is alloyed with another metal, such as lead or zinc, and heated to a certain point, the latter metals will separate and carry with them the silver, leaving the former. In practice this is done by fusing three parts of black copper and ten or twelve parts of lead, or an equivalent proportion of litharge rich in silver, in a cupola furnace, and running the molten mass out into moulds, where it is rapidly cooled by means of water, and removed in the shape of discs of about an inch or less in thickness. These are then to be heated

Fig. 333.



on a smelting hearth similar to that represented in Figs. 333 and 334 to the necessary degree, which determines the separation of the argentiferous lead by melting or sweating; this temperature is kept up as long as required. When as much as possible of the lead is removed, the discs appear in their original form, but very porous, still retaining an appreciable amount of the alloyed metals.

Fig. 334.



The hearth is composed of two cast-iron plates resting upon ledges of brickwork, and inclined towards each other, leaving a space, s, under which is a hollow channel, c. The discs of alloyed metal are placed perpendicularly upon these plates, their contact being prevented by pieces of wood. Charcoal is then thrown around and between them, the dividers being withdrawn; this is afterwards ignited by introducing some lighted faggots into the channel, c, and the smoke and gases carried on through draught-holes or chimneys, *d d*, in the walls of the hearth. As the plates become heated, the lead begins to flow, and falls upon the floor of the channel, which, being inclined, conducts it to a receptacle, *b*, whence it is taken and cast into moulds. Heat is applied to the plates as long as any metal separates, and when no more exudes they are taken to another furnace in which the temperature is more elevated, and where any portions still retained are recovered, and the black copper is left purer than after the first heating. It still retains some lead, together with traces of silver, but the former is entirely dissipated in the refining to which the cakes are subjected. Figs. 335 and 336 annexed, represent a plan and sections of a refining furnace used to convert the black copper of the foregoing operations into saleable metal; it is called split-hearths, or *spleiss-ofen* in Germany. In the plan, Fig. 334, *a* is the hearth where the charge is deposited; it is constructed of a mixture of coal-dust and clay, well beaten into a clay bottom, *b*, resting upon a bed of brickwork, *c*, all being supported by a slag bottom, *d*, arranged upon a foundation of gneiss. The letters *e* and *f* denote the upper and under discharge-holes; *g g* are the outlets leading to the split-hearths; *h h* and *i i* the masses of firebrick which are used to contract them till such time as the discharge of the metal takes place. The grate of the fire is seen at *l*, and *m* shows the bridge which wards off the hearth; the tuyeres are shown at *n*, and *o* is the chimney by which the gases evolved from the fire and metal are carried away. An elliptical form is usually given to the hearth of this kind of furnace, and its size is almost invariably about eight feet in its longest, and six and a half in its transverse diameter; the depth of the hollow in the bed is about ten inches. The two basins, *h h*, which are connected by an inlet, *k*, are floored in the same way as the hearth; they are generally about three to four feet in diameter, and sixteen inches deep, and are capable of containing a charge of twenty-five to thirty hundredweight of metal. About three tons of black copper are introduced into the furnace through the working door, *p*, together with more or less of granular copper and copper of cementation. The fire is then quickened, and when the charge has melted, the bellows are worked, and the stream of air directed on the surface of the bath. In a short time a coating of cinders and slag forms on the top, which is skimmed off; it is succeeded by a second and a third, which are removed each time as they make their appearance. When no more scoria is thrown off, the fire is increased, and the molten mass commences boiling, and continues so during three quarters or one hour, after which the commotion ceases, although the heat is not abated. The assayer now begins testing the relative purity of the metal by taking a sample out, and submitting it to the usual operations in the vice and under the hammer. In about three quarters of an hour after the boiling stops, and the first assay is taken, the refining is finished, and the preparations for running the charge are made; the furnace is then tapped, and the product received in the basins. During the flowing of the metal a reddish vapor is evolved; this consists of exceedingly small globules,

Fig. 335.

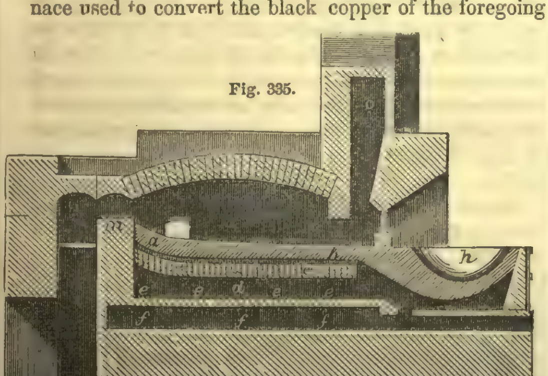
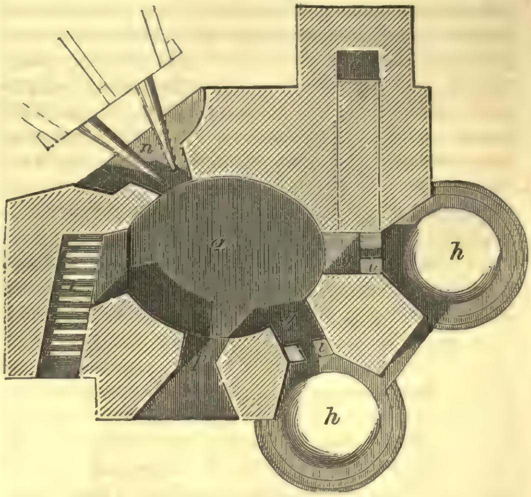


Fig. 336.



which revolve with great velocity upon their axes. They are found, upon analysis, to be composed of a nucleus of metal and an exterior coating of oxide of copper.

The metal is removed from the basins in rosettes or discs by sprinkling water upon the surface, and removing the cakes as they solidify, and immediately immersing them in water.

Fig. 337.

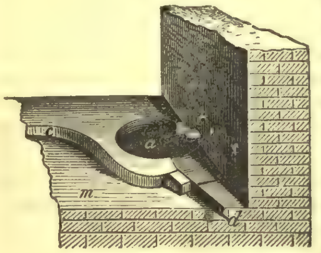
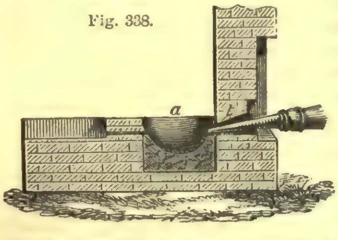


Fig. 338.



Sometimes a furnace is used for the purification of black copper, but especially that which has been liquated, to extract the silver, similar to Figs. 337 and 338. *a* is a hemispherical crucible sixteen inches in diameter, and rendered fireproof by a luting composed of two parts of powdered charcoal and one of fireclay; *c* is an iron curb for keeping the fuel from being scattered about during the melting; *b* is the masonry, and *t* the tuyere of the hearth. The mode of charging is to fill the crucible with charcoal in an ignited state to desiccate it, if required. When this is done, more fuel is introduced, together with pieces of black copper, which are deposited opposite the tuyere. The blast is admitted by degrees, and as soon as the metal of the first charge has been fused, a further quantity is put in, with as much charcoal as will effect the reduction, and the work is continued till the crucible becomes nearly full of metal. The scoria, as it is produced, flows off through an opening, *d*—Fig. 337—into the receiver, leaving the metal at the bottom. After the whole of the black copper requisite to form a charge has been operated upon, the attendant begins to examine the product in the usual way, by taking samples out of the bath by an iron rod, and immersing them into cold water. When the assay appears brownish-red on the outside, and of a coppery lustre interiorly, together with exhibiting much brittleness, the refining is said to be finished. The blast is now cut off, and the cinders and slag skimmed with the rake; some cold water is next sprinkled upon the surface of the pultaceous mass, and as soon as a solid crust is formed, it is removed and cast into cold water to prevent oxidation; more water is again thrown upon the metal, when another cake is formed, which is deposited in the tank in a similar way, and so on till the whole is converted into rosettes. Two and a quarter to two and a half hundredweight form the charge for the furnace of the ordinary size; but sometimes as much as seven hundredweight may be operated upon in one of these hearths. For the first, three quarters of an hour are occupied in the refining, and about a hundred and a half of metal in rosettes are obtained; but in the larger kinds of furnaces two hours are required. This product usually contains from one to two per cent. of other metals, such as lead, silver, iron, and aluminium. The first slag which is thrown off in this process has a greenish color, and retains a large quantity of oxide of iron, but little copper; the next scoria, however, has a deep red appearance, and retains a considerable amount of suboxide of the metal, and, therefore, is subjected to further operations in the preparation of the black copper. *Rosettes*, as thus prepared, are never sufficiently refined to allow the copper to be rolled out into sheets, or manufactured into the ordinary articles; consequently it has to undergo a further treatment. The plates are melted in a hearth like the preceding, and the surface of the bath is covered with charcoal, in order to deprive the metal of oxygen. Samples are taken from time to time, and examined with great precision, and as soon as the true grain is attained, the metal is cast into ingots. Sometimes the action of the charcoal is prolonged beyond due limits, and in such cases the product becomes injured; to bring it back, the refiner strips it of the charcoal, and directs the blast upon it, in order to expel any carbon which might have been taken up. By operating in this way, and with great caution, the bath is ultimately brought to its greatest degree of malleability. This metal bears a very high character for its purity, but it is said that it never excels the *selected refined* of the English smelter.

When the copper is refined it is cast into various shapes, to suit the wants of purchasers and manufacturers. *Bean* and *feathered shot* are produced by allowing the metal to flow into a large perforated ladle, set over a cistern of water. If the liquid be hot, the metal will assume the form of round grains, and in this state it is called *bean* shot; but if it be cold, they will be irregular, flattened, and ramified, and it is to this that the term *feathered shot* has been applied. Japanned copper is made by casting the refined metal into ingots, weighing about six ounces each; as soon as these solidify they are thrown, while yet hot, into cold water. In consequence of this treatment, the surface of the metal assumes a fine red color, owing to the formation of a slight coating of oxide. In this state the produce of English founders is largely exported to the East Indies.

Rolling.—Sheathing and other species of manufacture require the metal to be made into thin plates, a work which is done in the foundry by the aid of a powerful machine, called the rolling mill. The cylinders are usually about three feet in length and fifteen inches in diameter. In large establishments four pair of these are employed, and the whole moved by a steam-engine. The rollers are so placed that the upper may be brought nearer to the under one as the interposed body becomes thinner.

The refined copper is cast into ingots of a convenient size; and if the machine be on the premises, these are passed red hot whilst under the rollers. Should the rolling mill be at a distance, so that advantage cannot be taken of this, the ingots must be heated to dull redness in a reverberatory before they are submitted to the first flattening. Notwithstanding that the metal is very malleable, yet the requisite thinness is not communicated by one heating, because it readily cools, and acquires by compression a texture which impedes the lamination till the temperature be again raised. For this purpose the plates are heated successively after each rolling in an appropriate hearth, till they are expanded into sheets of twelve or fifteen feet in length and five in breadth. In consequence of being so repeatedly heated and cooled, the surface becomes coated with oxide of copper, which must be removed before packing. The course followed is to steep the sheets for four or five days in a tank filled with urine, and then to heat them on the hearth of the furnace, when, by the effect of the deoxidization of the ammoniacal salts, the scale becomes detached and the surface of the metal brightened. To assist the action, the operator rubs them with a piece of wood, and then plunges them while still hot into water. After this they are passed between the cylinders to give them a smooth face, and then cut into suitable squares and made up for sale.

ESTIMATION.—This terminates the account of the metallurgy of copper, so far as its production from the crude natural materials is concerned; yet, before closing, it may be as well to instruct the artificer so as to enable him, with certainty, to secure himself against imposition; and to give to the smelter such directions as will point out to him whether his procedure has been satisfactory or not. For this end both should be acquainted with the mode of *analysing copper and its compounds in the humid way*. The knowledge of the method of the dry assay, which is almost indispensable to the smelter, will not suffice when he has to determine what deteriorates the quality of his product, nor will it enable him to find what loss has been sustained during the several operations from the first roasting to the refining. Another great advantage which a knowledge of chemical analysis would guarantee, is the apportioning of all the ingredients in such a way as to insure the best decomposition, a thing which it is impossible to attain when an indefinite admixture, guided only by guess, is admitted to the furnace.

Copper may be estimated in several ways, but the most usual is by precipitation, as oxide, with a fixed alkali. When in combination with the other metals of its class, it is rarely separated from them, but the converse is generally the case; thus, when lead, bismuth, cadmium, silver, and such metals are present with copper in a compound, they must be removed before the latter can be determined; and as the ores of copper, and sometimes the refined metal, may contain more or less of one or other of these, it will be necessary to point out the system to be adopted. The dry method has already been given; but this does not always suffice, notwithstanding that, relatively, it might be satisfactory to the smelter, as he knows that by this mode of procedure, the assay is subject to similar sources of loss as when he smelts the ore in his reverberatories.

The three classes of compounds to be taken into consideration here, are the metal after refining, the ore before being submitted to the operations detailed, and the slags or scoriæ.

Copper, when obtained under the most circumspect surveillance on the large scale, is never pure, but contains other metals, varying in quantity from a decimal to one or two per cent. When these become appreciable, they exert a manifest injurious effect upon the metal, but then a lesser per centage of a certain impurity becomes much more prejudicial than a considerably greater amount of another. Thus a very small admixture of arsenic would destroy the malleability of copper, whilst a much greater proportion of silver would rather improve than deteriorate its value. It is for eliciting the real amount of copper in a sample, and also the nature of the impurities, that analysis becomes a matter of interest to the artificer or purchaser of the metal, for, as already stated, that sample which contains the largest per centage of copper will not be worked with the best advantage, provided certain deleterious substances, such as antimony or arsenic, be present.

Twenty or thirty grains of the ingot sample are taken and dissolved in a small flask with nitric acid by the aid of heat. The action of the acid is very brisk, and the evolution of nitrous fumes will be apt to carry off particles of the solution, unless the mouth of the flask be closed by a funnel. The copper, together with any silver, iron, lead, or zinc, which may be with it, is dissolved; and if antimony and tin had been contained in the original substance, they will be converted into insoluble binoxide of tin or teroxide of antimony. The liquor is concentrated to precipitate more completely the latter compounds, and dispel the excess of acid; after which water is added, and the precipitate filtered off and washed, the filtrate and edulcorations being afterwards submitted to further treatment. If silver be present, hydrochloric acid is to be added to remove it in the form of chloride, which, after subsidence, is to be filtered off, carefully washed, dried at 212° Fahrenheit, ignited in a tared porcelain crucible, weighed, and its per centage determined. The liquor filtered from the silver salt, together with the washings, is now treated with sulphide of hydrogen, to throw down the whole of the metals of this group which may be associated with the copper in the form of sulphides. The liquor should be acid, and the stream of gas ought to be continued until its odor is very perceptible. The beaker or vessel is now gently heated, and the precipitate afterwards collected upon a filter and edulcorated in the ordinary way, reserving the liquid to determine the iron which it might contain. During the filtration and washing, care should be taken that the sulphide be exposed to the air as little as possible; if this be neglected, the sulphide of copper will become oxidized, and pass through the paper in the state of sulphate, and, consequently, involve the trouble of a repetition of the precipitation and filtration with the risk of spoiling the assay. The sulphides are next digested with a solution of sulphide of potassium in a flask, to dissolve out any arsenic which may be contained therein, and, after the liquor has been removed, the residue is treated with weak nitric acid, filtered and evaporated to dryness with sulphuric acid. By this means the lead, if any be present, will be converted into the insoluble sulphate, which can be separated from the copper salt by washing with water upon a filter; and on drying the latter, burning, and weighing, the per centage of lead may be calculated from the result, since one hundred and fifty-two parts of sulphate of lead represent one hundred and four of the metal. If no other body be contained in the cupreous liquor, it is rendered moderately dilute by the addition of water, and heated nearly to ebullition, after which caustic potassa is added in excess. The oxide of copper thrown down is at first bluish, but on the further application of heat the water of hydration, which communicated the color, is removed, and the substance falls down as a dense black powder; it is collected upon a filter, and well affused with hot water till all the alkali is removed, after which it is dried in the bath, the matter separated from the paper on a glazed sheet of this material, and after the filter has been burned in the crucible till all the carbon has disappeared, the precipitate is introduced, the cover securely put on, and the whole heated over the lamp to redness. After this the crucible is weighed quickly, even while it is warm, and the quantity of the oxide of copper noted; if the weighing be not speedily executed water will be absorbed, and the result will be incorrect. Forty parts of oxide are equivalent to thirty-two of metal, and from this the per centage of copper contained in the sample under investigation may be found. For instance, if twenty-four and a half grains of oxide were obtained from the twenty grains taken after the weight of the filter ash has been deducted, the calculation would stand thus:—

As 40 : 32 : : 24·5 : 19·6, the quantity of metal in the sample; and again, As 20 : 19·6 : : 100 : 98·00 per cent.

The iron, in the filtrate from the precipitation by sulphide of hydrogen, may be estimated by adding ammonia and sulphide of ammonium, collecting the sulphide of iron which is produced, then dissolving it in dilute aqua regia, and boiling it to expel all traces of sulphide of hydrogen, after which ammonia is added in excess, when a brownish-yellow precipitate of sesquioxide of iron is determined. This is collected in the usual way, dried, burned, and weighed, and the per centage calculated.

The tin and antimony, separated in the first instance, may also be weighed, by treating the precipitate with tartaric acid, which will dissolve the latter; the tin may be collected, washed, dried, ignited, and its quantity ascertained. Seventy-seven parts of the binoxide represent fifty-nine of metallic tin. The antimony in the filtrate may be estimated by one or other of the methods laid down under that head at page 209.

Alloys of copper with other metals may be analysed in a similar manner; but as it would be tedious to give a detail of the method of estimating the alloyed bodies, this will not be further dwelt upon.

Ores of copper are analysed in nearly the same way as the foregoing, but differing, of course, according to the greater or less number of metals which they contain. From the list of the more commonly occurring minerals of copper given in the first part of this article, it will be seen that lead, tin, silver, arsenic, and iron, with occasionally nickel and cobalt, are the more frequent metallic concomitants; and sulphur, oxygen, carbonic acid, *et cetera*, the non-metallic combinations. The first steps to be taken in an analysis of such a compound are, to reduce the substance to fine powder, then to weigh out twenty to thirty grains of it, and treat it first with aqua regia to dissolve the copper, silver, lead, iron, nickel, and cobalt, and afterwards, when the solution of the nitrates has been filtered off, hydrochloric acid is poured upon the gangue and then boiled; what is left of the tin, antimony, and arsenic are by this treatment entirely carried off in solution, and nothing is left but silicious matter, which should be collected, dried, burned, and weighed. Both the nitric and hydrochloric liquors are now submitted to a stream of sulphide of hydrogen as long as any precipitation occurs. When this is accomplished the vessel is placed upon a moderately warm part of the sand-bath for some time, to precipitate any portions which might have been redissolved by the excess of the gas; the sulphides are next collected upon the filter, washed, and, subsequently, treated at a gentle heat with sulphide of potassium, to separate the antimony, tin, and arsenic. Filtration succeeds, and the residuary matter, consisting of sulphides of copper, silver, and lead, is treated as detailed in the foregoing. The metals dissolved by the sulphide of potassium are again thrown down in the state of sulphides, by adding hydrochloric or acetic acid to the liquid and applying heat. The precipitate is collected and washed, and then dissolved in aqua regia, containing an excess of hydrochloric acid; the excess of the solvent should be expelled by evaporation, and the residuary matter introduced into a flask connected with an apparatus, represented in Fig. 339, filled with nitrate of silver; and by acting upon it with zinc, the antimony and arsenic are transferred for the most part to the silver solution in the state of arsenide and antimonide of hydrogen, and the tin is left in the flask in the metallic state. In the annexed figure, A is the flask or bottle into which the metallic compounds together with zinc are introduced; some hydrochloric acid is put through the funnel-tube, B. The tube, C, carries off the hydrogen compounds of the metals to the apparatus D, where, in passing through the silver liquor in the bulbs, they become decomposed; the arsenide of hydrogen is converted into arsenious acid, and the antimony unites with the silver. This change is expressed in the following equations:—

$$\underbrace{6\,(\mathrm{Ag\,O,\,NO_5})}_{\text{Nitrate of silver.}} + \underbrace{\mathrm{As\,H_3}}_{\text{Terhydride of arsenic.}} = \underbrace{6\,\mathrm{Ag}}_{\text{Silver.}} + \underbrace{\mathrm{As\,O_3}}_{\text{Arsenious acid.}} + \underbrace{3\,\mathrm{HO}}_{\text{Water.}} + \underbrace{6\,\mathrm{NO_5}}_{\text{Nitric acid.}}$$

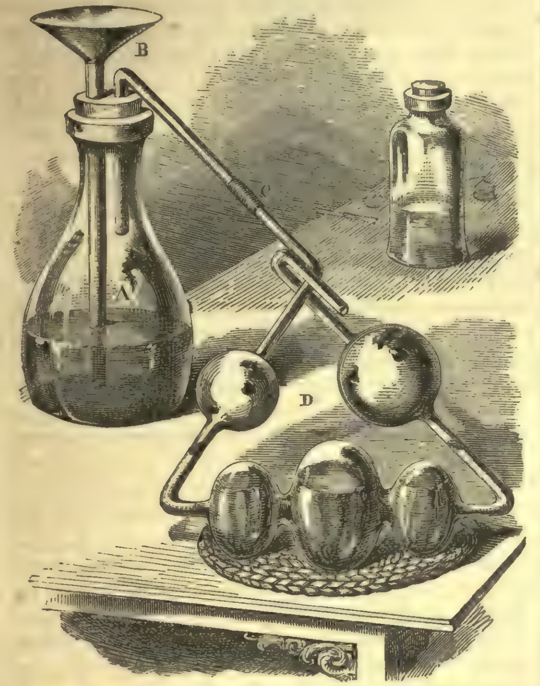
$$\underbrace{3\,(\mathrm{Ag\,O,\,NO_5})}_{\text{Nitrate of silver.}} + \underbrace{\mathrm{Sb\,H_3}}_{\text{Terhydride of antimony.}} = \underbrace{\mathrm{Ag_3\,Sb}}_{\text{Antimonide of silver.}} + \underbrace{3\,\mathrm{HO}}_{\text{Water.}} + \underbrace{3\,\mathrm{NO_5}}_{\text{Nitrate of silver.}}$$

In this decomposition the tin is reduced to the metallic state in the flask A, as also a portion of the arsenic and tin. After as much of the latter metals has been expelled from the flask as unites with the hydrogen, the apparatus is detached, the solution of zinc filtered from the precipitate, which is subsequently treated with hydrochloric acid to abstract the tin.

Should a residue remain, it will consist of antimony or arsenic, or both, and may be submitted to the treatment described at page 221 for their isolation.

The tin in the filtered liquid may be precipitated by a stream of sulphide of hydrogen, and the sulphide of tin collected, washed, dried, ignited in a porcelain crucible, and weighed as binoxide of tin.

Fig. 339.



By transferring the contents of the apparatus, *d*, to a beaker and then filtering, the solid antimonide of silver will be obtained; and by further washing and subsequently dissolving in nitric acid, it will be obtained as antimonious acid, which can be removed from the nitrate of silver, collaterally formed with it, by edulcoration upon a filter; and when this is done, it may be collected, washed, dried, its quantity determined, and this added to the preceding for the total amount. Sulphide of hydrogen may be transmitted through the arsenical liquor to throw down the metals, and after they are filtered the arsenic may be removed by sulphide of ammonium, and its quantity found in the ordinary way. The residue of the original precipitate, after the action of the sulphide of ammonium, should be dissolved in dilute nitric acid, and filtered from any portions of undissolved sulphur, then treated with sulphuric acid, and evaporated; this will afford the lead in the state of sulphate, which is to be collected, dried, and determined, as already pointed out. Addition of hydrochloric acid will remove the silver as chloride; and, if no other metal of this group be present, the copper in the filtrate and washings can be thrown down in the usual way by potassa. Iron, cobalt, *et cetera*, may be estimated by treating the original liquor from the sulphide of hydrogen precipitate with ammonia and sulphide of ammonium, filtering, and proceeding for the determination of cobalt, as directed under that article at page 491. If no cobalt be present, the amount of the iron is found by dissolving the sulphide in weak aqua regia, filtering from sulphur and adding ammonia to the solution, when a reddish-brown precipitate of sesquioxide of the metal will form. This is to be treated in the manner already described.

If lime had been contained in the mineral, it can be determined in the filtrate from the sulphide of iron, by adding carbonate of ammonia and boiling the liquid; carbonate of lime falls to the bottom, and must be collected, dried, detached from the filter, which should be burned alone on the lid of the platinum crucible, its ash added to the precipitate, and the whole heated for some time to low redness, then weighed. In this operation care must be taken that the carbonic acid is not expelled by too elevated a temperature; lest there should be such an occurrence, the analyst ought to reheat the lime salt with some powdered carbonate of ammonia in the same crucible, and after the whole of the volatile salt has been expelled, the latter is weighed; if both weighings agree, the determination is correct. Fifty parts of the carbonate represent twenty-eight of lime, and from this proportion the quantity of the base in the sample is ascertained.

When scoriæ are to be analysed, a different course must be followed, for generally these, in consequence of the vitrification of the metallic bases, are unattacked by acids. Such, however, as are decomposed by aqua regia or hydrochloric acid may be treated with these solvents, and when no further effect is produced by them, the residuary silica may be filtered, washed, dried, burned, and weighed. Sulphide of hydrogen may be transmitted through the liquor, and the sulphides treated as above directed. In fact, the same procedure as already recounted will answer for the analysis. Should the slags be so vitrified that the acids spoken of will have no effect upon them, they must be fused with carbonate of soda or baryta in a silver crucible to decompose the metallic silicates, and bring them to the soluble state. Occasionally there are metallic particles enveloped in the scoria, and if these came in contact with the crucible they would form an alloy, and the latter would be spoiled; therefore, to prevent this, it is necessary to have the sample ground, and to boil the twenty grains taken for the assay with nitric acid, filter, and wash. The residue remaining after this operation is dried, and afterwards intimately mixed with four or five parts of carbonate of soda and one of nitrate of potassa, and this mixture carefully deposited in a silver crucible. The cover is laid loosely on the mouth, and the whole put into a Hessian crucible containing some carbonate of magnesia to prevent contact. This is now heated strongly in a furnace for an hour, after which it is taken out, the crucible abstracted, and the contents removed by boiling water. Hydrochloric acid is added to the liquor, and the whole evaporated carefully to dryness; by this treatment the silicic acid is rendered insoluble, and on subsequently adding water acidulated with this reagent to the dry mass, it is left as a gelatinous residue. The liquor is now filtered and the precipitate washed well, the percolations being added to the rest of the filtrate, and while the silica may be drying, sulphide of hydrogen may be passed through it. Sulphide of copper, with others of the same class of metals, is thrown down. The further steps in the analysis are similar to those already detailed.

In the methods of analyses just described, the procedure is rather complicated, owing to the regard which is paid to the estimation of the other constituents; but when only the per centage of copper is to be found, a more expeditious and less laborious mode is adopted. Thus, when the mineral is dissolved in the acid, and the solution filtered, ammonia in excess is added thereto, which precipitates most of the metals accompanying the copper, and dissolves the latter, forming a rich purple liquid. On this being separated by filtration it is put into a flask, which it should fill to the neck, and one or two plates of copper, the weight of which is determined, introduced into the liquid; the flask is then closed, and deposited on a warm part of the bath, and left there till the blue liquor becomes colorless. This is the sign that the process is finished, and when observed the copper plates are taken out, washed, dried, and weighed; from the loss of weight which they sustain, the quantity of copper in the solution is indirectly ascertained. The *rationale* of the operation is, that the protoxide of copper is converted to suboxide, and in this transformation eight parts of oxygen are given up to the metal by eighty parts, or two equivalents of the oxide; this unites with the metal dissolved from the plates, and takes up two equivalents, producing a suboxide, thus:—

$$\underbrace{2\,CuO}_{\text{Oxide of copper.}} + \underbrace{2\,Cu}_{\text{Copper.}} = \underbrace{2\,(Cu_2O)}_{\text{Suboxide of copper.}}$$

From the formula it will be seen that two equivalents of the oxide afford as much oxygen as will convert two atoms of the metal into suboxide, so that the loss which the plates sustain equals the weight of copper in the sample taken.

For the better success of the experiment, it is necessary that no air should enter into the flask during the time that reduction is being effected, because any oxygen absorbed from this source would completely destroy the results. All the bases which might be dissolved by the excess of ammonia ought likewise to be removed before introducing the copper plates, otherwise they would render the experiment useless, by combining with more oxygen, or yielding this element to the metal.

Copper has been determined in mineral compounds by a method proposed by PELOUZE some time ago, and which is founded on the simultaneous precipitation and decoloration of an ammoniacal solution of copper by sulphide of potassium or sodium. In this operation much preliminary work is requisite before the test can be applied, because the standard liquor would be expended in precipitating other metals of the same group as copper, were they present. More facilities for making the determination seem to be offered by the process lately proposed by PARKES, and which is on the volumetrical principle.

One or two ounces of pure cyanide of potassium or sodium are dissolved in a certain quantity of distilled water, and retained in a well-stoppered bottle for use. Ten grains of pure copper are dissolved in dilute nitric acid by the aid of heat, taking care not to employ too large an excess of the solvent; ammonia is then added to the liquor till the precipitate, which at first forms, disappears, and the solution is of a fine purple. The test liquor is now added to it carefully from a burette in successive small portions, stirring after each addition till the blue solution becomes colorless. When this happens, the number of measures is read off and noted to serve as a standard, whereby to determine the metal. A quantity of the ore under examination is weighed out and boiled with *aqua regia* in a small flask till all the metals are dissolved, when the liquor is filtered and treated with ammonia in excess; this reagent precipitates the iron and most of the other metals, holding the copper dissolved. After digestion at a gentle heat, the solution is filtered, and the residue edulcorated well with water, adding the washings to the filtrate, and testing this liquor with the alkaline cyanide till the decoloration is effected. If manganese be present, carbonate of ammonia should be substituted for ammonia, because the oxide of this metal is not insoluble in the caustic alkali, and the solution of the cyanide would cause a yellowish tint in the liquor, which might, to some extent, be found to interfere with the detection, when the blue would have disappeared. Again, if arsenical compounds be contained in the ore, the arsenic will be converted into arsenic acid by the action of the nitric acid, or *aqua regia*, and will escape precipitation by the ammonia; but this may be remedied by adding a small quantity of protochloride of tin, which will deoxidize it, so that it may be thrown down in the form of arsenious acid, and the latter is removed as stannic acid by the alkali.

The calculation of the results is made as follows. Supposing that, for the decoloration of the ten grains of copper dissolved in ammonia, forty measures on the burette were required, and that thirty sufficed for the twenty grains of ore, then—

As 40 : 10· :: 30 : 7·5 grains of metal; and again,

As 20 : 7·5 :: 100 : 37·5 the per centage of copper in the samples. Several other methods have been given whereby the quantity of copper may be ascertained, but it is unnecessary to enter into further details.

STATISTICS.—The annual produce of copper is subject to some variation, owing to the difference in the richness of the veins producing it. There are about one hundred and eighty mines in the United Kingdom, of which one hundred and thirty-six are in Cornwall, twenty-seven in Cumberland, seven or eight in Wales, and six or eight in Ireland. In Swansea and other parts of England and Wales, about eighteen thousand five hundred tons of copper are annually produced, the average price of which ranges from ninety to one hundred and fifty pounds per ton, according to circumstances, and supposed to be influenced in a great measure by the smelters.

The following Tables show the average weekly sales of copper ore at Cornwall, and its money value, during the last five years. All the ore sold at Swansea is likewise tabulated quarterly, and the total for the year added to the annual Cornish produce.

SALES OF COPPER ORES AT PUBLIC TICKETING IN CORNWALL AND SWANSEA, JAN. 1850, TO DEC. 1854.

Date.	Average Standard.	Average Produce.	Average Price per Ton.			Quantity of Ore.	Quantity of Fine Copper.		Amount of Money.		
1850.			£	s.	D.	21 Cwts.	Tons.	Cwts.	£	s.	D.
January 3,	109·5	7⅛	5	1	6	3785	271	3	19,217	11	6
„ 10,	106·7	8¼	5	17	6	2247	182	3	13,196	6	6
„ 17,	102·2	10	7	9	6	2343	234	19	17,547	19	0
„ 24,	112·1	7⅝	5	15	6	3573	272	4	20,685	18	6
„ 31,	114·3	7¼	5	9	0	4040	291	5	22,147	5	6
February 7,	110·6	8¼	6	3	0	2408	194	14	14,885	1	0
„ 21,	107·5	9¼	7	5	6	2806	261	1	20,279	9	0
„ 28,	116·10	6½	4	16	6	2846	185	0	13,726	7	0
March 7,	113·6	7¼	5	10	6	3869	282	18	21,409	18	6
„ 14,	107·15	8⅛	6	0	6	2846	232	3	17,187	1	6
„ 21,	101·14	9¾	7	3	0	2662	259	9	19,074	17	6
„ 28,	107·17	7¾	5	4	0	4183	307	11	21,674	3	6
April 4,	107·18	7	4	17	0	4612	325	0	22,388	9	6
„ 11,	102·14	8	5	9	6	2978	238	13	16,319	11	0
„ 18,	97·10	9¼	6	6	0	2958	274	7	18,621	0	6
„ 25,	108·18	6½	4	7	0	2246	146	7	9,766	11	0
May 2,	107·19	7	4	16	0	3350	255	13	16,216	10	6
„ 9,	105·4	7¾	5	8	0	2780	216	5	15,106	6	6
„ 23,	98·3	9½	6	11	0	2619	248	5	17,165	0	6
„ 30,	103·3	7½	5	0	0	4276	320	18	21,351	2	6
June 6,	105·7	6¾	4	7	6	5083	343	5	22,186	13	0
„ 13,	99·11	8	5	4	6	3663	292	9	19,050	3	6
„ 20,	95·8	9¼	6	0	6	2993	275	8	18,041	6	6
„ 27,	105·6	6⅝	4	3	6	2122	139	15	8,882	6	0
July 4,	104·6	7¼	4	16	0	3665	264	8	17,504	18	0
„ 11,	97·14	9¼	6	3	6	2490	227	12	15,395	2	6
„ 18,	96·7	8⅝	5	11	0	2640	227	5	14,644	6	0
„ 25,	100·6	7⅞	5	3	6	3314	262	13	17,237	15	6
August 1,	102·18	7	4	9	6	4518	318	12	20,361	18	6
„ 8,	96·9	8⅜	5	6	0	2882	240	3	15,236	4	0
„ 22,	91·19	9⅝	6	2	6	3244	313	12	19,992	10	0
„ 29,	104·14	6⅜	3	19	6	2386	153	12	9,523	12	0
September 5,	104.13	7¾	5	2	6	3988	310	2	20,542	19	6
„ 12,	100·11	8½	5	16	0	3106	262	9	17,854	6	6
„ 19,	96·13	9½	6	8	6	2670	253	7	17,149	14	0
„ 26,	101·10	8	5	7	6	3491	279	18	18,818	2	0
October 3,	105·8	7⅛	4	15	0	4700	334	14	22,354	1	6
„ 10,	99·12	8⅜	5	11	6	2788	233	12	15,604	14	0
„ 17,	96·3	9½	6	7	6	3009	285	4	19,141	12	0
„ 24,	105·9	7	4	12	0	2325	162	3	10,705	15	0
„ 31,	105·18	7⅛	5	4	6	2564	269	2	18,699	8	0
November 7,	100·8	8⅜	5	12	6	2565	213	10	14,388	4	6
„ 21,	96·3	9½	6	8	0	2766	263	13	17,752	14	6
„ 28,	103·19	7⅝	5	3	6	3547	270	8	18,350	7	6
December 5,	106·13	6¾	4	8	6	4835	325	19	21,465	11	6
„ 12,	102·6	8	5	8	0	3674	292	5	19,809	17	6
„ 19,	97·13	9⅝	6	13	0	3172	305	10	21,118	0	0
„ 26,	110·1	6⅝	4	9	6	2398	157	9	10,732	1	6
	....	....	....			154,005	22,377	17	704,510	16	0
Foreign, Irish, and Welsh Ores,..	....	....	13	2	4	41,713	......		549,276	14	0
Total for the Year 1850,..	....	....	....			195,718	......		1,253,787	10	0
January 2, 1851,	110·10	6¾	4	15	0	3546	240	19	16,868	0	0
„ 9,	104·18	8⅜	6	0	0	2326	193	19	13,959	15	6
„ 23,	95·4	9½	6	6	0	2613	249	0	16,527	11	6
„ 30,	102·13	7½	4	18	0	3322	247	19	16,323	1	6
February 6,	104·15	6¾	4	7	0	4799	325	13	20,922	15	6
„ 13,	100·17	7⅞	5	4	0	3240	255	14	16,886	18	0
„ 20,	95·19	9⅛	5	19	0	3057	277	18	18,257	17	6
„ 27,	105·2	6¾	4	6	6	2406	161	14	10,384	8	0
March 6,	103·3	7¼	4	14	6	3487	252	12	16,463	12	6
„ 13,	98·8	8⅝	5	15	0	2262	195	18	13,061	6	0
„ 20,	94.12	9⅜	6	2	6	2565	240	5	15,677	18	0
„ 27,	101·1	7⅞	5	4	0	3237	255	13	16,941	7	6
April 3,	104·14	6⅞	4	8	6	4628	315	19	20,352	17	0
„ 10,	102·1	7⅝	5	0	6	2983	226	18	14,950	2	6
„ 17,	95·7	9¼	6	1	0	3163	291	14	19,115	5	0
„ 24,	103·9	7¼	4	14	6	2545	183	10	11,983	5	6
May 1,	103·10	8⅛	4	12	6	3334	238	15	15,550	12	0
„ 8,	100·10	8	5	5	6	2273	181	13	12,009	19	0
„ 22,	95·5	9⅛	5	18	6	2806	254	9	16,531	4	0
„ 29,	103·6	7¼	4	14	6	3848	276	14	18,001	10	6
June 5,	104·1	7	4	11	0	4575	321	7	20,863	12	0
„ 12,	100·9	8	5	6	6	3594	288	18	19,145	16	0
„ 19,	94·17	9⅝	6	7	6	3283	315	19	20,945	6	0
„ 26,	103·10	7⅛	4	11	6	2670	188	15	12,206	4	6
July 3,	100·12	8⅛	5	8	0	3377	273	16	18,265	14	0
„ 10,	99·14	8¼	5	10	0	2541	210	13	14,015	14	6

SALES OF COPPER ORES IN CORNWALL AND SWANSEA—CONTINUED.

Date.	Average Standard.	Average Produce.	Average Price per Ton.			Quantity of Ore.	Quantity of Fine Copper.		Amount of Money.		
			£	s.	d.	21 Cwts.	Tons.	Cwts.	£	s.	d.
1851.											
July 17,	95·19	8⅞	5	16	0	2842	252	15	16,443	12	6
" 24,	102·5	7⅝	5	0	6	2986	225	17	14,881	19	6
" 31,	103·10	7⅛	4	13	0	4172	299	17	19,562	19	6
August 7,	102·4	7¼	4	19	0	2775	209	14	13,804	0	0
" 21,	95·6	9⅜	6	4	6	3183	299	17	19,822	17	0
" 28,	103·8	7⅛	4	11	6	2401	170	7	11,011	10	6
September 4,	102·2	7⅝	5	0	0	3505	266	4	17,544	5	0
" 11,	99·1	8⅛	5	13	0	2848	241	9	16,081	9	0
" 18,	95·13	8⅞	5	15	0	2630	233	13	15,182	5	6
" 25,	101·3	7¾	5	2	0	3197	249	10	16,450	3	6
October 2,	103·2	7¼	4	14	6	4367	317	5	20,700	11	0
" 9,	102·	7½	4	18	0	3025	227	12	14,896	2	6
" 23,	98·12	9¼	6	7	0	3546	327	16	22,587	3	6
" 30,	105·12	7⅛	4	16	0	2271	163	4	10,998	11	6
November 6,	105·4	7¼	4	17	6	3317	240	17	16,221	17	0
" 13,	103·13	7⅜	5	6	0	2941	228	14	15,621	8	6
" 20,	99·7	8⅝	5	16	6	2828	243	9	16,413	3	6
" 27,	104·4	7⅜	5	3	0	2999	226	16	15,390	19	0
December 4,	107·18	7⅛	4	18	6	3853	272	5	18,793	11	6
" 11,	105·9	7¾	5	8	0	2895	224	3	15,676	13	0
" 18,	100·16	8¼	5	15	0	3317	280	16	19,182	0	0
" 25,	107·18	6⅞	4	13	6	2002	138	16	9,470	16	6
	....	....	....			150,400	11,807	0	782,950	3	6
Foreign, Irish, and Welsh Ores,..	....	....	12	4	6	39,838	......		492,422	19	6
Total for the Year 1851,..	....	....	....			190,238	......		1,275,373	3	0
January 1, 1852,	105·9	7⅞	5	8	6	2965	230	6	16,139	11	0
" 8,	104·15	7¼	5	10	0	2894	228	11	15,985	7	0
" 22,	103·6	8⅜	5	18	0	2839	237	4	16,694	9	0
" 29,	110·19	7	5	0	0	3197	222	18	15,948	8	0
February 5,	113·10	6¼	4	12	6	4366	284	11	20,281	1	0
" 12,	109·19	7⅜	5	3	6	3951	302	5	22,377	15	0
" 19,	105·10	8¾	6	2	0	3690	310	0	22,550	16	6
" 26,	112·4	6⅝	4	19	6	2184	151	2	10,948	8	6
March 4,	111·18	7	5	1	6	3250	228	15	16,667	3	6
" 11,	110·12	7⅞	5	19	0	3230	254	17	19,317	11	6
" 18,	105·7	8⅜	6	9	0	2650	233	3	17,273	17	6
" 25,	112·16	7⅛	5	5	6	2895	205	4	15,191	1	6
April 1,	114·6	6¾	4	19	6	4142	280	0	20,625	3	6
" 8,	110·14	7¾	5	16	6	3781	294	11	22,214	12	0
" 22,	108·3	7⅞	5	16	0	3758	296	16	21,773	9	6
" 29,	116·4	6⅜	4	13	0	2526	160	18	11,748	9	0
May 6,	114·2	6¼	5	1	6	3848	261	6	19,322	14	0
" 13,	112·11	7⅛	5	14	0	3250	245	3	18,625	18	0
" 20,	109·14	8¼	6	6	0	3176	260	5	19,823	1	6
" 27,	117·8	6¾	5	4	0	2999	204	4	15,734	4	6
June 3,	118·18	6⅜	5	2	0	3980	262	10	20,268	9	6
" 10,	117·10	8	6	13	0	3222	256	10	21,270	10	0
" 17,	114·8	8	6	11	0	3753	304	17	24,553	2	0
" 24,	123·6	6¾	5	11	6	2457	165	18	13,705	3	0
July 1,	127·18	6½	5	12	0	2934	192	0	16,501	1	6
" 8,	125·6	7⅜	6	9	0	3047	223	0	19,565	9	6
" 22,	120·6	8¼	7	3	6	3161	261	12	22,785	7	6
" 29,	129·4	6⅞	6	2	0	3460	236	12	21,054	19	0
August 5,	130·5	6½	5	14	6	4450	291	15	25,769	4	0
" 12,	130·4	7	6	7	0	4113	285	10	25,867	19	0
" 19,	124·11	8¼	7	10	6	3829	316	6	28,866	5	0
" 26,	136·8	6⅛	5	11	6	2928	178	15	16,324	12	6
September 2,	134·12	6¼	6	0	0	3295	213	19	19,744	4	0
" 9,	133·14	6⅞	6	5	0	3124	214	6	20,063	4	0
" 23,	127·14	7⅜	6	19	6	3352	255	9	23,399	15	0
" 30,	135·4	6⅜	6	4	0	3756	247	8	23,124	11	0
October 7,	140·7	6	5	13	6	4543	272	0	25,681	1	6
" 14,	131·8	7⅛	6	12	6	4219	301	5	27,983	8	6
" 21,	126·16	7½	6	15	6	4299	322	4	29,031	7	6
" 28,	135·4	6	5	7	6	3115	188	6	16,891	13	6
November 4,	133·6	6⅜	5	15	0	3063	194	3	17,450	6	0
" 11,	131·12	6¾	6	3	6	3427	233	6	21,276	3	6
" 18,	127·18	7¼	6	10	6	3459	251	14	22,687	11	0
" 25,	133·10	6½	5	18	6	3532	229	7	20,898	19	6
December 2,	136·5	6	5	8	6	4432	267	16	24,305	13	6
" 9,	134·6	6½	6	0	0	3883	254	4	23,467	18	6
" 23,	132·	7¼	6	16	0	3819	275	0	25,807	2	0
" 30,	145·19	5⅝	5	9	6	3369	189	9	18,387	10	6
	....	....	....			165,502	11,767	0	975,974	14	0
Foreign, Irish, and Welsh Ores,..	....	....	14	13	4	31,654	......		464,314	16	0
Total for the Year 1852,..	....	....	....			197,156	......		1,440,289	10	0

SALES OF COPPER ORES IN CORNWALL AND SWANSEA—CONTINUED.

Date.	Average Standard.	Average Produce.	Average Price per Ton.			Quantity of Ore.	Quantity of Fine Copper.		Amount of Money.		
			£	S.	D.	21 Cwts.	Tons.	Cwts.	£	S.	D.
1853.											
January 6,	147.18	6⅜	6	14	6	3293	211	19	22,293	12	0
" 13,	152·5	6¾	7	10	6	3262	220	7	24,575	6	0
" 20,	152·6	7⅛	8	14	0	3411	256	19	29,753	15	0
" 27,	164·14	5¾	6	14	0	3192	182	8	21,265	17	0
February 3,	161·18	6⅛	7	3	0	4355	264	8	30,832	10	6
" 10,	157·17	6⅜	7	14	6	3495	233	5	27,205	12	0
" 17,	155·1	7⅛	8	6	0	4627	331	6	38,643	17	6
" 24,	165·12	5⅝	6	12	0	2936	166	16	19,556	0	6
March 3,	164·9	6⅛	7	6	0	3283	199	2	23,714	8	0
" 10,	161·6	6½	7	14	0	4032	261	18	31,149	8	6
" 17,	154·4	6⅝	7	11	0	3859	257	19	29,172	9	6
" 24,	160·11	5⅝	5	18	0	3411	185	7	20,380	8	0
" 31,	154·8	5¾	6	3	0	4531	262	10	28,071	6	0
April 7,	144·17	6¼	6	6	6	4769	300	11	30,423	1	6
" 21,	130·18	6⅝	5	18	6	5936	334	0	29,879	14	6
" 28,	127·17	5⅛	3	16	0	4297	220	19	16,435	0	6
May 5,	118·6	6⅛	4	10	0	3821	233	7	17,097	9	0
" 12,	118·17	6⅛	4	11	6	4730	291	19	21,693	10	0
" 19,	113·7	7¼	5	9	6	3392	247	3	18,689	14	6
" 26,	128·17	5¾	4	13	0	3731	214	10	17,384	13	0
June 2,	127·10	6	4	18	0	4764	285	6	23,260	10	6
" 9,	124·14	7	5	19	0	3432	241	14	20,572	8	0
" 23,	120·16	7½	6	6	0	4681	350	7	29,458	1	0
" 30,	130·1	6	5	1	6	3146	190	9	16,117	1	6
July 7,	127·16	6⅛	5	11	6	3147	205	18	17,660	6	0
" 14,	124·6	6¾	5	12	0	4405	296	12	24,764	8	6
" 21,	120·19	7¼	6	2	6	3615	264	6	22,022	3	0
" 28,	127·10	6⅜	5	7	6	2887	185	1	15,655	3	6
August 4,	127·18	6¼	5	4	6	4488	279	18	23,460	1	0
" 11,	126·13	7	6	2	6	3587	251	7	21,966	0	0
" 18,	124·2	7⅜	6	8	0	4452	328	7	28,496	16	6
" 25,	131·10	6⅛	5	15	0	2922	189	8	16,875	11	0
September 1,	132·3	6½	5	16	6	2655	172	1	15,438	7	0
" 8,	132·14	6⅞	6	7	0	3850	262	14	24,280	3	6
" 22,	127·7	7⅝	6	19	0	3790	289	17	26,496	10	0
" 29,	133·13	6⅝	6	2	6	2938	195	11	18,054	8	0
October 6,	137·15	6¼	5	17	0	4684	291	4	27,230	12	0
" 13,	136·3	6⅞	6	13	0	4365	302	3	29,134	6	0
" 20,	134·19	6⅞	6	10	0	4684	320	19	30,428	14	6
" 27,	141·12	6	5	16	0	2974	179	14	17,270	15	0
November 3,	139·3	6¾	6	12	0	2356	158	14	15,604	13	6
" 10,	143·1	6⅞	7	1	6	3947	271	0	27,918	2	6
" 17,	141·16	7⅜	7	13	6	3818	282	7	29,531	15	6
" 24,	147·	7⅜	8	1	0	2464	180	16	19,806	14	0
December 1,	153·19	6⅜	7	2	0	4394	282	11	31,424	7	6
" 8,	150·13	6¾	7	0	6	4386	297	19	32,839	3	6
" 22,	148·14	6⅜	6	15	0	4699	300	9	31,753	3	6
" 29,	152·14	6⅛	6	12	0	2951	180	8	19,429	3	6
	....	....	....			182,844	11,913	13	1,155,167	3	6
Foreign, Irish, and Welsh Ores,..	....	....	14	9	10	32,974	......		477,861	18	6
Total for the Year 1853,..	....	....	....			215,818	......		1,633,029	2	0
January 5, 1854,	148·14	6½	6	18	0	2926	189	14	20,167	6	0
" 12,	149·	6½	6	19	0	4180	271	16	29,009	6	6
" 19,	146·19	6½	6	15	0	4156	269	4	28,116	11	6
" 26,	148·19	6¼	6	11	6	2846	179	5	18,868	15	6
February 2,	150·17	5⅞	6	1	6	4168	243	1	25,200	14	0
" 9,	149·2	6½	6	18	6	4749	307	14	32,814	13	0
" 23,	144·13	6⅝	6	16	6	4419	292	0	30,092	1	0
March 2,	150·	5⅝	5	15	0	3739	212	5	21,562	14	6
" 9,	147·13	5⅞	5	18	6	2685	158	12	16,037	10	0
" 16,	147·19	6	6	1	0	4140	245	18	24,992	13	0
" 23,	139·18	6⅞	6	17	6	4390	302	14	30,271	16	0
" 30,	139·8	6	5	13	6	3020	183	2	17,219	15	0
April 6,	142·17	5½	5	2	6	4190	232	8	21,687	12	6
" 13,	139·16	6½	6	7	0	4988	324	6	31,624	10	0
" 20,	140·5	6⅜	6	10	0	4409	290	4	28,579	13	0
" 27,	146·12	5¾	5	14	8	3391	196	18	19,541	5	6
May 4,	146·4	6½	6	13	6	2287	147	6	15,251	7	0
" 11,	146·5	6⅝	6	17	6	3790	249	3	26,014	10	6
" 18,	139·11	7⅛	7	3	6	3966	282	3	28,471	2	0
" 25,	144·	6	5	16	6	3321	197	11	19,320	3	6
June 1,	145·1	5⅞	5	14	6	3352	195	3	19,093	17	0
" 8,	139·8	7⅛	7	2	6	4573	323	17	32,564	16	6
" 22,	141·4	6⅜	6	4	0	4340	276	1	27,037	4	0
" 29,	142·11	5¾	5	9	0	4204	240	3	22,674	17	0
July 6,	140·17	6½	6	1	0	2791	175	6	17,015	18	6
" 13,	137·17	6¾	6	11	0	4577	308	1	29,877	0	0

SALES OF COPPER ORES IN CORNWALL AND SWANSEA—CONCLUDED.

Date.	Average Standard.	Average Produce.	Average Price per Ton.			Quantity of Ore.	Quantity of Fine Copper.		Amount of Money.		
1854.			£	s.	d.	21 Cwts.	Tons	Cwts.	£	s.	d.
July, 20,	136.11	6⅝	6	6	0	4327	287	7	27,341	3	0
,, 27,	140·1	6⅜	6	3	0	3502	222	6	21,502	3	6
August 3,	143·16	5¾	5	10	6	3235	186	13	17,947	3	0
,, 10,	136·9	7½	7	2	0	5222	376	12	37,028	0	6
,, 17,	139·2	6¼	6	0	0	4199	264	2	25,185	11	0
,, 24,	140·	6⅛	5	17	0	3180	195	10	18,619	19	0
,, 31,	142·16	5⅞	5	13	0	2585	152	15	14,704	5	0
September 7,	137·11	7⅛	7	0	0	4447	315	0	31,097	12	6
,, 21,	138·4	7	7	0	0	3975	280	8	27,812	13	6
,, 28,	143·10	6½	6	10	6	3688	238	6	24,054	10	0
October 5,	144·13	5¾	5	11	6	3884	224	10	21,792	7	0
,, 12,	139·7	6¾	6	13	6	5054	343	9	33,960	12	0
,, 19,	142·	6¼	6	2	0	4582	285	7	27,930	3	0
,, 26,	147·2	5⅞	5	18	6	3547	210	4	21,171	8	6
November 2,	144·14	6½	6	13	0	2229	145	4	14,880	1	0
,, 9,	142·19	7	7	5	6	4375	308	11	32,077	16	0
,, 23,	141·8	6⅞	6	18	6	4333	295	17	29,912	10	0
,, 30,	141·12	6⅝	6	12	6	4095	273	0	27,400	2	0
December 7,	145·10	6⅛	6	2	6	3712	225	9	22,596	17	6
,, 14,	142·12	6¾	6	17	6	4857	327	15	33,383	19	0
,, 21,	141·6	6⅛	5	18	0	4698	287	7	27,690	12	6
,, 28,	242·17	5⅞	5	13	6	3780	224	4	21,642	6	6
	....	....	...			187,103	11,964	11	1,092,835	9	0
Foreign, Irish, and Welsh Ores,..	....	....	14	2	5	36,683	......		518,106	5	0
Total for the Year 1854,—	....	...	...			223,796	......		1,610,941	41	0

SALES OF FOREIGN, IRISH, AND WELSH COPPER ORES AT SWANSEA, FOR THE YEARS 1853 AND 1854.

Date.	Quantity of Ore.	Average Price.			Amount of Money.		
1853.	Tons.	£	s.	d.	£	s.	d.
Quarter to March 31,	5,119	17	17	11	91,622	11	6
" to June 30,	8,444	13	13	5	115,441	7	6
" to September 30,	10,089	12	5	5	123,801	10	6
" to December 31,	9,322	15	15	4	146,996	9	0
	32,974	14	9	10	477,861	18	6
1854.							
Quarter to March 31,	7,037	14	15	1	103,838	15	6
" to June 30,	9,708	13	16	8	134,294	2	0
" to September 30,	10,921	13	6	0	145,282	2	6
" to December 31,	9,017	14	18	9	134,691	5	0
	36,683	14	2	5	518,106	5	0

M'CULLOCH gives the following table of exports of British copper *in hundredweights*, from 1820 to 1852:—

Years.	Unwrought.	Coin.	Sheets, Nails, *et cetera.*	Wire.	Wrought Copper of other Sorts.	Total of British Copper exported.
1820,	41,155	10	58,121	8	22,663	121,958
1825,	10	2,134	51,437	40	25,002	78,624
1830,	56,722	640	66,331	16	56,443	183,154
1835,	39,409	—	100,807	49	20,219	161,524
1840,	20,355	391	119,266	39	10,427	150,478
1845,	195,727	618	154,859	83	9,493	360,781
1850,	154,678	148	263,007	357	7,962	426,153
1851,	112,245	1,510	221,013	715	15,628	351,111
1852,	118,266	957	201,887	2,424	15,187	338,721

The quantities of copper and copper ore imported into the United Kingdom, *in tons*, in the years 1853, 1854, and 1855, were as follows:—

	1853.	1854.	1855.
Copper ore and regulus,	50,393	57,292	66,599
Copper—unwrought and part wrought,	5,200	3,218	8,044

The following quantities were exported during the same years:—

	1853.	1854.	1855.
Copper—unwrought and part wrought,	1,640	1,253	951

In 1842, the duty on copper ores and unwrought copper was very materially reduced, and was wholly repealed in 1853.

COPPER ALLOYS.—Although the uses of unmixed copper in the arts are various and highly important, yet, when combined with other metals, it is productive of compounds which, in an industrial point of view, are fully as useful as itself, and applied much more extensively. It is on this account that the alloys of the metal will now be described; but as all of them have not as yet been fully investigated, to ascertain whether or not they are capable of being serviceable in the arts, only such as are known to be so will be considered in detail.

Probably copper is capable of entering into combination with all the metallic elements severally, although this has not been hitherto effected. With potassium and sodium it forms alloys which are not of common occurrence, although it is supposed that a small quantity of these metals confers on copper the property of malleability to a high degree. DUMAS, who examined an alloy of this description, and who suggests the addition of cream of tartar—bitartrate of potassa—to the fused metal as a means of producing it, found the annexed results:—

	Centesimally.
Copper,	99·12
Potassium,	0·38
Calcium,	0·33
Iron,	0·17
	100·00

Aluminium, manganese, and cobalt, form combinations with copper after some time; but the alloys are with more difficulty prepared, and are less interesting in point of utility, than several others which will be noticed presently; iron also is difficult to alloy with it, still compounds of this nature occur, but usually in the presence of tin. The principal part of the *black copper* described in the preceding pages is composed of copper and iron; and a mixture of these metals, in the proportion of one hundred parts of grey cast-iron and five of copper, yields an alloy which is of considerable hardness, and therefore has been proposed by RINMANN as an improved material for anvils. The presence of iron, however, renders copper brittle, and of a coarse grain; on the other hand, it was found by FARADAY that the latter injures the quality of steel, and MUSHET states that it renders cast-iron brittle. Its combinations with nickel, zinc, lead, tin, and the precious metals, are more useful, and, therefore, have been more particularly studied than the foregoing, or than its compounds with cadmium, antimony, and arsenic, which have been hitherto of no great use.

Before entering on the details of the subject, it may be well to say a few words upon alloys in general, and to explain some of their peculiarities.

ALLOY, a term which the French render *alliage*, and the Germans *legirung*, was once exclusively applied to mixtures of other metals with gold and silver, but later times have linked with it the signification of any mixture of the metals, except mercury, the combinations of which are still known as *amalgams*. It is evident that alloys, being composed of metallic bodies, will possess all the physical and chemical characteristics of metals; they have the metallic lustre, are more or less ductile, malleable, elastic, and sonorous, and conduct heat and electricity in a remarkable manner. In retaining these properties, however, the compound is so modified in each, that it does not resemble either of its constituents, and might, consequently, be regarded as a new metal, having distinctive characters peculiar to itself. This is especially the case with those which are extensively used in the arts, and which will be presently described. It would almost seem that there is no department of the arts requiring the use of metals for which an alloy may not be prepared, possessing the requisite qualities, when these are not found in the simple or original metals. The method of preparing them, however, has not yet been generalized, and has even in not a few instances failed, owing to the very meagre amount of information which has been gained upon the subject. The ten or a dozen metals in use, if studied with care, are capable of producing several thousand alloys; but of these not more than fifty or sixty have been strictly examined, so that it may be said that the art of alloying metals is yet in its infancy. Before this branch of industry becomes invested with that importance which it is doubtless destined to attain, the chemist must devote his attention to a close examination of the various compounds which are capable of being produced, and must assign to each, by describing its properties and relations, its special sphere of utility. The metallurgist, if left to himself, cannot be expected to arrive at certain results, because, probably, he may be wanting in chemical knowledge, or in the methodical course of investigation which must be possessed by those who are qualified to prosecute successfully such researches. These qualifications are so much the more indispensable, when it is remembered that every new alloy, by the fact of its properties being different from those of its constituents, may be regarded as a new metal. Many instances might be cited in which the qualities of the compound are quite different from those of the alloyed constituents, but to follow this subject minutely is unnecessary, the fact being generally well known; one or two examples, however, may not be uninstructive. The type-founder, for example, could not, for a long time, procure castings possessing such qualities as those at present known, owing to the metals singly not being adapted to his purpose; they were either too hard, and gave castings which cut the paper on which they were intended to print, or too soft, and flattened under the weight of the press, besides, they would not afford castings having that accuracy of outline which is necessary to print well. By mixing lead and antimony—the former a soft and tenacious, and the latter a hard and brittle metal—an alloy resulted possessing all the requirements, and which has been consequently known as *type metal*. Again, the bell-founder could not employ singly with advantage any of the known metals, because they were deficient in the quality he chiefly required, namely, sonorousness; but by combining copper and tin in various proportions, he is enabled to construct bells which are capable of producing every intonation in the musical scale. Many examples of a parallel nature might be mentioned, to show that the product of the union of two or more metals is a distinct homogeneous body, having characteristics peculiar to itself, and different from those composing it; but this will be shown more in detail in connection with the several metals as they pass individually under review.

Many alloys consist of simple elements in definite or equivalent proportions, whilst others are produced from compound bodies, and often the components do not exist in the ratio of their chemical equivalents. Metals, in forming alloys, do not, however, combine indiscriminately with one another; the union is governed by the greater affinities which some of them manifest for each other, just as, in the chemistry of bases and acids, a predisposing attraction determines a preference. This, in some measure, proves that chemical combination is exercised, and that the alloys are not merely mechanical mixtures, but definite chemical compounds. All the true alloys which have been hitherto examined tend to corroborate this fact; and it is probable that peculiar properties belong to the combination when prepared in atomic proportions, such as is done in making the superior quality of brass. It is remarkable, also, that the native gold found in auriferous sands and rocks is alloyed with silver in the ratio of one equivalent of the latter to four, five, six, eight, ten, *et cetera*, equivalents of the former; but the combinations never afford results indicative of the metals being united in fractional parts of an equivalent. Another proof of the chemical combination subsisting is, that the compound melts at a lower temperature than the mean of the fusing points of its ingredients. An instance very remarkable in itself is the alloy of eight parts of bismuth, five of lead, and three of tin; this compound fuses at the temperature of boiling water, although the melting point deduced from the mean of its constituents is 514° Fahr. Thus, iron, when alloyed with gold, enters into fusion at nearly the melting point of the latter metal, although, when alone, it is one of the most infusible elements.

Again, as the melting point of the alloys differs from the mean of their constituents, so also, when the affinity between the metals is very great, the compound is generally denser than the mean, and *vice versâ*, as exemplified by the following compounds:—

Alloys, the density of which is greater than the mean of their constituents.	Alloys, the density of which is less than the mean of their constituents.
Gold and zinc.	Gold and silver.
Gold and tin.	Gold and iron.
Gold and bismuth.	Gold and lead.
Gold and antimony.	Gold and copper.
Gold and cobalt.	Gold and irridium.
Silver and zinc.	Gold and nickel.
Silver and tin.	Silver and copper.
Silver and bismuth.	Iron and bismuth.
Silver and antimony.	Iron and antimony.
Copper and zinc.	Iron and lead.
Copper and tin.	Tin and lead.
Copper and palladium.	Tin and palladium.
Copper and bismuth.	Tin and antimony.
Lead and antimony.	Nickel and arsenic.
Platinum and molybdenum.	Zinc and antimony.
Palladium and bismuth.	

Indeed, the degree of the affinity between metals may be, in some measure, estimated by the greater or less facility with which, when having a different point of fusibility or volatility, they unite; or with which, when united, they are separated by heat. The greater or less tendency to separate into other alloys by prolonged fusion, may also serve to give information on the subject. Hatchett has already performed some experiments of this nature by making alloys of gold with silver, copper, lead, and antimony, of the standard proportion; and after long fusion, casting them in vertical ingots; the analysis of the several parts of these afterwards showed that the composition was not homogeneous, but that the top portion of the bar corresponding to that metal which was in the bottom of the crucible, contained more of the gold than the other parts. This is also the case in every instance where there is a notable difference of gravity between the constituents, unless great pains be taken to cause the metals to combine more perfectly; because, during the fusion, the chief portion of the heavy metals will assume a level in the crucible in the order of their respective densities, unless they are prevented doing so by stirring with a porcelain rod. A partial separation of the metals takes place sometimes in the casting, even when all the attention possible may have been bestowed on the alloy during its formation; this is more especially the case if the casting be large, and slow in cooling, such as cannons and the like, in which the lower portion will often be found to contain an excess of copper, and the upper too much tin. The remedy for this is a refusion of the articles, and after this the mixture will be found nearly homogeneous.

Great art is required in the preparation of alloys, especially when they contain more than two metals; for it is not uncommon to observe two alloys of exactly the same composition differ very materially in properties, in consequence of a difference in the mode of preparation. This change often arises from the application of a higher temperature than usual, or from the order in which the fusion of the components is effected; to these points attention will be directed as the several compounds are described, and more especially in regard to the alloys of copper, which subject will now be resumed.

Most of the combinations of copper have been already alluded to; and, in consequence of the unimportance of many of them, only a few of the most useful will claim particular attention under the present head. Such are those which copper forms with zinc and tin, and which are known under the general titles of brass and bronze.

BRASS.—*Laiton*, *cuivre jaune*, French; *Messig*, German.—It would appear from several passages in sacred as well as profane history, that no metallic compound was in more general use with the ancients than brass, it being apparently the best known to them. Tubal-cain is described as a worker in brass—copper (?) From the writings of Moses and Ezekiel also, the general use of brass is inferred, although it was evidently ranked in value far below silver and gold, as appears from the following passage, which also touches on other matters relating to ancient metallurgy:—*The house of Israel is to me become dross; all they are brass and tin, and iron, and lead, in the midst of the furnace; they are even the dross of silver.*

Further than frequent mention, however, the sacred writers do not go; they leave the mode of manufacture in obscurity, as indeed do most of the profane historiographers of subsequent ages. Pliny says that a flourishing trade in brass was carried on in Rome shortly after the founding of that city, and that Numa, the immediate successor of Romulus, formed all the workers in this alloy into a kind of community. Subsequently, the above authority gives a particular account of various alloys employed for casting, soldering, brazing, *et cetera*, and even mentions the proportions that were used. The circumstance of his thus dwelling upon these compounds must have arisen from the fact, that they had been invested with the utmost interest by the Greeks and Romans, who had most of their coins and statues cast of them; and not these only, but all their implements of war and conquest were made of cupreous alloys, as appears from Homer's account of Pisander's engagement with Agamemnon, which is thus translated by Pope:—

> An olive's cloudy grain the handle made,
> Distinct with studs, and *brazen* was the blade.

As already indicated, these alloys were not the same as those designated brass at present, but modifications of bronze. The first account of the alloy of copper and zinc transmitted to the present times was written by Aristotle; he states that the people who inhabited a country adjoining the Euxine Sea, prepared their copper of a beautiful white color, by mixing and cementing it with an earth found there, and not with tin, as was seemingly the custom. Strabo also alludes to the preparation of the alloy of copper and zinc by the Phrygians, from the calcination of certain earths found in the neighborhood of Andêra; and other authors, in the time of Augustus, speak distinctly of cadmia, and its property of converting copper into *aurichalcum*, under which title the zinc alloy was subsequently known. Several writers of the Christian era who have referred to this compound, are not more explicit than their predecessors; still it is evident, from various recent analyses of old alloys, that zinc was contained in many of those prepared about the commencement of the present era.

The several compounds produced by the combination of copper and zinc in different proportions, are included in the generic term *brass*. Many of these, however, present great differences in their physical appearance and properties. Alloys of copper and zinc may be made to assume every shade of color, varying from the whiteness of the latter metal to the deep color of gold, by a judicious admixture of the constituents. These varieties have been distinguished by fanciful specific names, as Prince Rupert's metal, pinchbeck, Mannheim gold, tutenag, tombac, similor, arcot, potin, *et cetera*. In the manufacture of the brass in ordinary use by the more ancient method, an impure alloy is obtained in the first stages, which is the arcot above mentioned; potin is formed in a similar way, when the finer quality of brass is made; both of these compounds contain a great many impurities.

Prince Rupert's metal consists of about equal weights of copper and zinc; pinchbeck and Mannheim gold are similar to this, but they contain more copper, as also do the other alloys mentioned, and on account of their golden color are employed to some extent in jewellery. When this is the case, it is customary to fuse the copper previously with potassa, in order to effect its depuration from any adventitious matters, or probably with the view of rendering it more malleable, as has been already explained. In the manufacture of brass, great care should be taken to secure it against the presence of iron, which offers many inconveniences in the working. This metal does not chemically combine with it in large quantities, but is usually found disseminated in small magnetic particles throughout the mass. Its occurrence happens when an impure calamine is employed in the manufacture, or when old brass containing it is the source of the copper. It renders the alloy prone to rust and tarnish when exposed to the air; making it also hard and dull, and considerably diminishing its tenacity and malleability.

Traces of tin and lead are occasionally detected in various kinds of brass, and sometimes these metals, instead of being injurious, are found to be somewhat advantageous. Their presence arises from the employment of old brass which had been tinned over or soldered. Lead is present from the employment of rosette copper, which had been eliquated to separate the silver, and which still retains some of the lead then employed; its use is mostly confined to the Continental founders. This brass, although it is harder and more brittle than the ordinary kind, is more easily worked under the lathe, but that which is dry is generally preferred by the turner; it may be welded together, and the junction is not easily broken; in addition, it can be cut with a chisel, sawn, and perforated with facility and exactness. The composition of this variety of brass is seen in the annexed table taken from Dumas:—

	Unknown.	Stolberg.	Plate brass of Stolberg.	Plate brass of Jemmapes.
Copper,	61·6	65·8	64·8	64·6
Zinc,	35·3	31·8	32·8	33·7
Lead,	2·9	2·2	2·0	1·5
Tin,	0·2	0·2	0·4	0·2
	100·0	100·0	100·0	100·0

The proportion of zinc may be varied within certain limits, but when these are exceeded, the results are not in much request. Practice has fixed the extremes of these between thirty and thirty-eight per cent. of zinc, but as occasion requires, the quantity may fall short or exceed this with advantage. Thus, when a rich alloy of considerable tenacity is required, the zinc is reduced to twenty-five per cent., while with one of little resisting power, fifty per cent. of zinc may be used; and should a hard and very brittle compound be desired, the zinc is raised to sixty per cent.

The alloy used as gilding metal is mostly the same as the foregoing. It should be easily melted, and flow freely. It admits of being engraved and turned with facility, and of being gilt with the smallest possible quantity of gold. The latter quality arises from the fact, that the grain of the brass is very fine and compact, so that none of the precious metal is obscured. All the alloys which are devoted to these uses are not, however, homogeneous in their composition, as the appended analysis of a few of them will show:—

	Centesimally represented.				
	1.	2.	3.	4.	5.
Copper,	63·70	64·45	78·48	78·84	82·3
Zinc,	33·55	32·44	17·22	17·31	17·5
Tin,	2·50	0·25	2·87	0·96	0·2
Lead,	0·25	2·86	1·43	2·89	0·0
	100·00	100·00	100·00	100·00	100·0

The densities of the first and second alloy here mentioned are respectively 8·395 and 8·542, and they are reputed by D'Arcet to be the best adapted for the purposes of the jeweller. In the other three samples the amount of copper is much larger, although intended for the same purpose, and very often it is increased to ninety and ninety-five per cent., in which case it is analogous to chrysocolla. The product is then called gilding metal, while the others are similar to Bath metal, pinchbeck, Mannheim gold, and similor. Lead and tin, as already stated, do not affect the quality of the brass so much for certain works; but where it is requisite that the latter should retain its tenacity as much as possible, the least quantity of these metals will prove detrimental. Thus appreciable amounts of lead or tin would be highly injurious in brass of which it is intended to make wire; nevertheless, this kind of alloy always contains traces of other metals, as the following analyses of wire-brass will show:—

	Centosimally represented.	
Copper,	66·2	67·0
Zinc,	33·0	32·0
Tin,	0·8	—
Lead,		0·5
Antimony,	—	0·5
	100·0	100·0

They contain a larger quantity of zinc than is usual in this country, but all the manufacturers do not follow the same proportions.

Another variety of brass, which is employed in operations where it is requisite that the metal should work well under the hammer, is composed of copper and zinc in the following proportions:—

	Centesimally represented.
Copper,	70·1
Zinc,	29·9
	100·0

Metal which is in general use in the manufacture of pieces of machinery and locomotives, has the composition annexed:—

	Centesimally.
Copper,	74·5
Zinc,	25·0
Lead,	0·5
	100·0

The fracture of this alloy is of a fine yellow color; it is not so malleable as those in which the quantity of zinc is less. Generally, as the per centage of zinc increases, the malleability is decreased; hence, for working brass, the best varieties are obtained when the zinc constitutes from twenty to thirty-three per cent. of the whole.

Many other varieties besides those mentioned are prepared; but instead of further referring to their centesimal composition, it may be well to give the formula in the language of the working brass-founder. In this it is the custom to specify the amount of zinc only, it being understood that the ratio is to the pound of copper. Thus, when chrysocolla is being formed, or when it is desired to give the copper the property of casting well, one-eighth to half an ounce of zinc is alloyed with each pound of metal. The manner in which this is sometimes done, is by fusing four ounces or less of brass with the above quantity of metal. The proportion reckoned upon in making the gilding metal already alluded to, is one to one ounce and a quarter of zinc; and, like the foregoing, this alloy is not made by the union of its components directly, but by the fusion of a definite proportion of brass and copper. In red sheet brass the pound of copper is proportioned to three ounces of the secondary metal.

Mannheim gold, pinchbeck, Bath metal, and several other alloys, all of which possess more or less of an auriferous appearance, are formed with three or four ounces of zinc to the pound. The true brass, from which all the other varieties are called, is formed of two parts of copper and one part of zinc; and metal which bears soldering well, such as Bristol brass, contains a smaller quantity of the secondary metal.

The following table exhibits the proportion in which these are employed, namely:—

	Bristol brass.	Muntz metal.	Muntz sheathing.	Spelter solder.	Pale yellow metal.	Mosaic gold, Hamilton's.
	oz.	oz.	oz.	oz.	oz.	oz.
Copper,..	16	16	16	16	16	16
Zinc,....	6	10⅔	9 to 16	12 to 16	12	16½ to 17

In the preceding alloys it is always necessary to employ more of the secondary metal than is here mentioned, in order to cover the quantity which is dissipated by the great heat usually resulting from the union of the two metals; unless this precaution be taken, or provision be made for preventing the volatilization of the zinc, the resulting alloy will often be found quite different from what was intended.

Having thus far given a rapid view of the nature and composition of the various kinds of brass, it will now be proper to give an account of the process followed in the manufacture. Long before the isolation of zinc, and when, consequently, the combination with copper could not be effected as is now generally done in brass-foundries, the ancients were well acquainted with brass and the method of preparing it. The course then followed was to fuse the copper with an ore of zinc and charcoal, by which treatment the zinc was reduced and combined with the copper without becoming known as a distinct body. Calamine, blende, and other compounds of zinc were used in the manufacture, but it was customary for these to undergo a calcination before they were fused with the copper and charcoal. The old method is still pursued in some cases where it is thought to be more advantageous than to melt the respective metals together.

The materials which the founder employs in manufacturing brass in this way are bean copper or rosettes, from which the silver has been abstracted by eliquating with lead, calcined calamine, blende, or the cadmie of blast furnaces and charcoal, the proportion of the latter two being regulated according as it is intended to produce red or yellow copper.

In this method it is of great importance that the mineral of zinc be of a good quality, free from any sulphurous compounds, and also from silicate of zinc; the former is injurious, inasmuch as it renders the alloy brittle and of a bad color, and the latter is not reduced in the crucible in the ordinary way, although, by the aid of lime or carbonate of lime, it may be made to yield its zinc to the copper, while the silica flows off in combination with the earthy base. Another matter of importance is, that the material should be well calcined, otherwise the reduction of the zinc will be more difficult than if the roasting was properly executed. Frequently, this operation is performed by placing alternate layers of calamine and coal or charcoal upon one another in the form of a mound, the base being constituted of large billets of wood, and igniting the mass as in the calcination of alum shale.

The following analysis of three samples of calamine will illustrate the disadvantage of inferior calcination, *et cetera*:—

	Centesimally represented.		
	Calamine badly calcined.	Calamine of superior quality.	Calamine of ordinary quality.
Oxide of zinc,..............	66·0	69·0	64·7
Oxide of iron, ...	2·9	7·4	8·6
Water and carbonic acid,....	28·5	0·2	7·2
Silica and sand,............	2·6	23·4	19·5
	100·0	100·0	100·0

In these three samples, if the silicic acid was converted in the reduction to the state of silicate, all the zinc would be obtained through the agency of the charcoal; but it is not often that this is the case, and, consequently, much of the zinc becomes useless. The roasted mineral is prepared for the operation of smelting and uniting it with the copper, by grinding it under head-stones, and subsequently sifting to remove the grosser particles. When this is operated upon with rosette grain or bean shot copper, the alloy can seldom be made richer in zinc than twenty-seven or twenty-eight per cent.; and before the article in general use can be obtained, the product resulting from the fusion with calamine, kiess or cadmie, must be melted, and a fresh quantity of the secondary metal introduced, in order to bring it to the marketable standard. Sometimes it is the custom to employ old brass and other cupreous matters in founding the metal in this way; in such cases it always happens that some impurities in the shape of lead, iron, tin, *et cetera*, are incorporated, one or more of these being already in combination in the metal employed as the source of copper. Two distinct operations are followed in preparing the brass by this method; the first, to form the alloy just mentioned, generally known as *arcot*, and the second, to render this marketable by combining it with a further proportion of zinc. It would appear, however, that no advantage arises from this course, but rather the reverse; for if the requisite proportion of the alloyed metal had been taken, one fusion would suffice, and the consumption of fuel would be considerably diminished.

Indeed, of late years the manufacture of brass has been conducted on this plan almost generally, especially in England, and apparently with great advantage, and doubtless the method will very soon be general. In making brass, furnaces like those described for smelting copper are never employed, but the fusion is effected in large crucibles or pots, placed in a circular hearth, as in the case of bismuth.

Figs. 340 and 341 represent the furnaces used in the brass-foundry. The first is a general plan of a foundry, in which five furnaces on one side are represented, while the corresponding ones on the other side are not shown. A A A indicate the kilns or ovens in which the brass is formed by the action of heat upon the materials employed. C C C are the doors of the ash-pits of the furnace, shown in Fig. 341; and B is the pit into which the clinkers are collected. D D are the coverings of the flues to the chimney; they are supported by posts fixed in the channels. E E, wooden boxes in which the calamine is kneaded with charcoal preparatory to smelting it. In performing this operation water is employed—this affords great assistance—but the mass is completely dried before submitting to the pots. F F F, large slabs of granite stone used for moulding the brass; G G G, pits in which the stones are turned by means of a wheel and axle; and I I I, pivots on which they move.

Fig. 340.

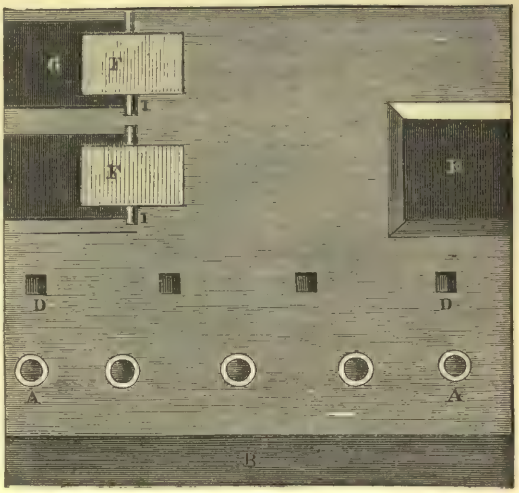
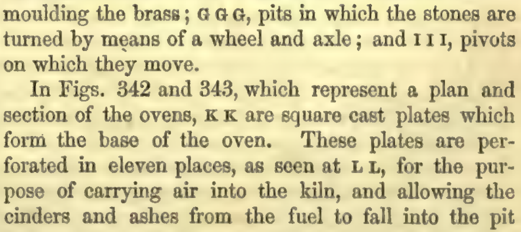


Fig. 341.



In Figs. 342 and 343, which represent a plan and section of the ovens, K K are square cast plates which form the base of the oven. These plates are perforated in eleven places, as seen at L L, for the purpose of carrying air into the kiln, and allowing the cinders and ashes from the fuel to fall into the pit beneath. M M, the area or floor of the kiln, made of refractory clay. N N are the pots for fusing the material, of which eight are in each kiln; and O O O, the arches of these. They are cast in moulds, and are composed of the same material as that of which the pots are made, only so much care is not bestowed upon them as upon the latter. When finished, the mould, which is constituted of seven or eight parts, is sundered. The arch is some inches flat at the base, that it may press strongly and securely. P P P represent the top casting, which forms the mouth of the kiln, opening into the cover, D D, of the foregoing figure, and which rests upon the arch.

The height of the kilns equals their breadth, which is about one foot and a half. They are each capable of holding six or eight pots, the capacity of which is such as to contain collectively from one to one and a half hundredweight of brass. The fuel employed in these operations is generally coke, although coal may be used; it should be in pieces of moderate size, so as not to intercept the draught. Small coal or slack, if used, should be mixed with a little clay, and made into cakes, which, when dry, might be broken into pieces of the size of an egg. The furnace and pots being heated, the attendant takes one of the latter and fills it to the brim with the mixture of calamine and charcoal, and then forces into it the necessary quantity of the rosette or grain copper, or of arcot, by a few blows of a mallet or hammer, and after this is done, sprinkles a few handfuls of the charcoal mixture on the surface. The crucible is then taken and deposited in the fire, and the others charged in the same way in succession, till the kiln is replenished. Pieces of fuel are then added in such quantities and in such a manner that the pots shall be surrounded and covered, but not overloaded with them. The furnace is then closed, and left undisturbed for six or seven hours, keeping up the temperature. At the end of this period the contents of the pots are at a white heat; the fire is again revived with the addition of more fuel, and kept in active combustion for a short time, until the fumes of the volatilizing zinc, which are significant of the reduction and fusion of this metal, appear. As soon as this happens it is slackened, in order that the copper may not melt too rapidly, and thus prevent its prolonged exposure to the fumes of the melted zinc, which exposure is very necessary to insure a good combination. During a further period of three or four hours, the heat should be managed with a view to this end, so that the copper, as it melts drop by drop, may present a large amount of surface to the other metal. About three or four hours serve to effect this process. After the combination has taken place, the pots are removed from the kiln, and the gross matters are separated first, then the dross or portion of oxide on the surface, and both these products deposited in appropriate receptacles. Finally, with a kind of ladle, the attendant detaches any particles which may be adhering to the bottom or sides of the pot, and when, ultimately, he has the metal well cleaned, he proceeds to the casting.

Fig. 342

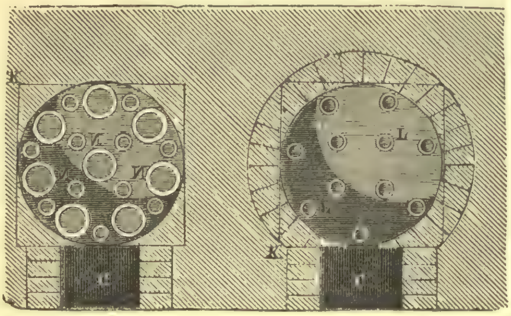
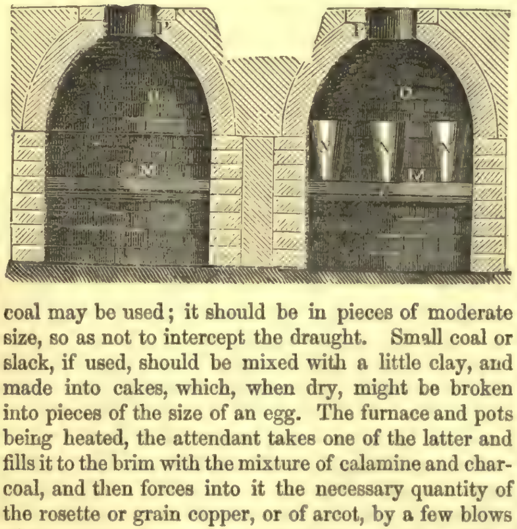


Fig. 343.



At Holywell, in North Wales, where a considerable quantity of brass is annually founded, the manufacture is carried on mostly on this principle. The calamine is found mixed with a large quantity of lead ore, but before being used the latter is very efficiently removed by picking, grinding, and washing, and the former is left in a finely divided state. The calcination is then performed in the ordinary way, and with the usual precautions of stirring, *et cetera*, in a furnace of considerable area, the bed of which is almost horizontal. After the roasting, the material is reduced to powder in a mill, and at the same time mixed with about one-fourth of its weight of charcoal. The crucibles or pots, which are made of refractory clay, are filled with this mixture, and the proper amount of red or grain copper; the covers are then luted on with a material composed of refractory clay and horse dung. The proportion of the materials are for the most part—

40 pounds of grain copper, and
60 „ of calamine and charcoal mixture;

from which sixty pounds of brass, containing thirty-three per cent. of zinc, are obtained. The period of reduction and combination extends over twenty-four hours; but this, of course, varies with the nature of the materials, the size of the furnace, *et cetera*. The use of the copper in a finely divided state offers considerable advantage in the preparation of good brass, as it presents, during the fusion of the materials, a large surface to the zinc. The completion of the process is known to have arrived when, owing to the volatilization and combustion of the zinc emitted through the cracks in the luting, a bluish flame and a white smoke is observed. The moulds employed for brass are usually made of blocks of granite bound together with iron, and having the intervening space regulated by bars of iron, the thickness of which corresponds to the intended casting. Sometimes, however, they are of cast-iron, and answer all intended purposes remarkably well. Fig. 344 annexed, which represents a workman in the act of pouring the metal into the mould, will give the reader an insight into this part of the business; but this arrangement is principally made use of in casting the finished article. The arcot which the preceding fusion affords is composed centesimally of eighty parts of copper and twenty of zinc, and the materials requisite for producing one hundred pounds are about eighty-one pounds of rosette copper and the same quantity of calamine, or of a mixture of this and kiess, and from forty to fifty pounds of ground charcoal. In finishing this product into brass, it is customary to employ two mixtures, one or other of which is selected according as the brass is required for the lathe or otherwise. A metal possessing much tenacity, and working well under the chisel, is obtained by employing—

Fig. 344.

24	pounds of	yellow copper,
20	"	" alloy,
45	"	arcot,
66	"	calamine and kiess mixed, and
16	"	ground wood charcoal.

These materials are well fused together, and when the combination has been thoroughly effected, and the alloy has fallen to the bottom of the crucible, from six to seven pounds of zinc are added, in successive portions, taking care to immerse them in the molten bath. About one hundredweight of alloy is thus produced, containing—

	Centesimally.
Copper,	65·4
Zinc,	34·6
	100·0

This brass is used for wire-drawing, and hence is cast into plates of the appropriate thickness. The other mixture yields a product which is more ductile, and can be welded with greater facility than the above; it is as follows:—

33	pounds of	rosette copper,
11	"	yellow alloy,
44	"	arcot,
66	"	mixture of calamine and kiess,
16	"	charcoal.

In addition to these, about nine pounds of metallic zinc are used at the end of the fusion, to complete the mixture. The yield is nearly the same in both cases. In each, much of the zinc remains without being combined, so that it is not easy to pronounce which is the more advantageous.

Tinsel and foil are prepared from this alloy, and the quality which suits for these purposes is obtained from the small quantity of lead contained in the rosettes, or else intentionally added, although not taken into account in the formula.

Very often old brass of various kinds is used as a constituent in these mixtures, and through them old nails and fragments of metallic iron have been introduced, and very often they are found in the product, contributing not a little to lower its quality. Iron is also derived from the calamine or other zincous materials operated upon. Chemical combination, however, does not take place between the substances, and the particles of the foreign impurities are only in mechanical suspension; so that if sufficient time be allowed for the metal to repose, all of these will be thrown off as scum, and thus the alloy becomes purified at little trouble and cost. The skimmings generally contain some particles of brass, which can be separated by washing or cribbling, when the alloy, by virtue of its greater specific gravity, will be found at the bottom, mixed, however, with other matters; but these may be removed by the hand.

In fusing the mixtures already alluded to, there are no scoriæ produced, nor, indeed, in any mixtures of the kind, all the silicious ingredients being united with large portions of other matters which do not enter into fusion at the temperature of the kiln or pot. Hence the great loss which results from the use of zinc compounds which contain a large amount of this metal in the form of silicate, for, besides what is liable to be lost by the oxidation of some of the reduced metal, all this passes off unchanged. Much labor is attendant upon the manufacture of brass, as already shown, and the expenditure in fuel is such that not more than one-half the quantity is requisite when the alloy is made by fusing the metals together. Another advantage in the latter mode is, that more than double as much as could be procured by the old method can be formed in twenty-four hours with far less labor. To conduct this, however, in a manner which would reduce casual loss, is attended with difficulties, against which the operator must guard. The principal one is the rapidity with which the zinc is deprived of its property of alloying with the metal, owing to its affinity for oxygen. For this reason, when the proportions of an alloy as determined by chemical analysis are synthetically employed to form a similar article, generally the result will be a failure; either more of the metal prone to oxidize must be employed, so as, by this excess, to make up for that which becomes lost, or some means must be adopted to exclude the *foul* air, as it is inappropriately termed in the language of the workman. Covering the alloy with suitable fluxes renders great service in this respect, not only in preventing the oxidation, but, as a consequence of the first, excluding this oxide from afterwards mixing with the metal and injuring its quality. Hitherto, however, it seems that it is impossible to get rid of this great difficulty to the brass-founder, and the nearest approach to it is said to have been made by Lord Rosse, who recommends a furnace or kiln deeper than usual, and the covering of the metal at all times with a layer of powdered charcoal two inches thick. When these conditions are fulfilled, it is affirmed that only about the hundred and eightieth part of the metal is lost; whereas, according to the most accurate experiments recorded by **HOLTZAPFFEL**, the least was about a thirtieth of the whole alloy. This gentleman fused twenty-four pounds of copper, and determined the loss which was thus sustained. An equal weight of the same material was afterwards fused; twelve pounds of best quality of zinc in plates of about three-fourths of an inch thick, were then broken up into convenient-sized fragments, which were added one by one at regular intervals to the fused copper, till the whole was introduced. When this happened, the surface of the liquid compound metal was covered with glass, and left to the action of the heat for fifteen minutes, or till such time as the fumes of zinc gave indications that the contents of the pot were in perfect fusion. Having removed the pot from the fire, and the matter therein being stirred for a short time, it was cast, and the result of two experiments thus conducted, showed that, instead of obtaining 33⅓ per cent. of zinc, the proportion found was 31¼, or 7¼ ounces of zinc instead of eight to the pound. Further, on remelting quantities of this alloy, it ceased not to lose zinc, so that after the sixth operation the alloyed metal was reduced to 4⅝ ounces to the pound; in each of these, however, the deficiency was not generally the same, the second fusion indicating most loss.

Brass is chiefly manufactured in England and France; in the former to a much larger extent than in the latter. The total quantity fabricated cannot be accurately ascertained, but it is annually increasing, more especially since the introduction of gas into cities, which has given rise to numerous and extensive branches of trade in this metal.

GERMAN SILVER.—**BRITISH PLATE, ARGENTAN**; *Cuivre blanc*, *Maillechort*, French; *Argentan*, *Neusilber*, *Weisskupfer*, German.—This is an alloy of nickel, copper, and zinc, which owes its peculiarity more to the first than to the other metals; still, as the copper is the main ingredient, a brief account of it will be given here as one of the copper alloys. It has long been known to the Chinese under the name *pakfong*, or white metal, but Europeans have not been acquainted with it for more than a century, and its application to useful purposes in the arts dates not even so far back. Latterly, however, considerable business has been done in this alloy, especially in applications for household and decorative use among the middle classes of society. It has been introduced into this country from Germany, as its name implies, where it had been prepared, for the first time in Europe, by smelting an ore found at Hilburghausen, near Suhl, in Henneberg. The analysis of the original preparation afforded **KEFERSTEIN** the appended results:—

	Centesimally.
Copper,	40·4
Nickel,	31·6
Zinc,	25·4
Tin,	2·6
	100·0

The Chinese pakfong always contains two to three per cent. of iron, and this is said to give it a brighter color, and to render the alloy more compact; but then it confers hardness and brittleness also, and these militate against its use in many cases. As the nickel necessary to prepare the compound is much rarer than the other constituents, metallurgists have considerably diminished the proportion of this, substituting zinc; in doing so, the argentiferous brightness of the alloy is not much impaired, so long as the ratio remains within a certain limit, but once this is passed, the compound presents a fair appearance for a short time, and then assumes the hue of pale brass. The following table represents the composition of a number of these alloys, according to the analyses of several competent chemists:—

Centesimally.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Copper,	43·8	40·4	53·4	50·0	65·4	60·0	57·0	59·2	55·0	51·6	45·7
Nickel,	15·6	31·6	17·5	18·7	16·8	20·0	20·0	14·8	20·6	25·8	34·3
Zinc,	40·6	25·4	29·1	31·3	13·4	20·0	20·0	26·0	24·4	22·6	20·0
Iron,	—	2·6	—	—	3·4	—	Lead, 3·0	—	—	—	—
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

Numbers one and two are the analyses of samples of Chinese pakfong, the latter being a very superior quality in point of color and structure, so that it can be very highly polished. Three and four represent the composition of alloys prepared by **FRICK**. They resemble very much a silver alloy containing about eighteen carats to the ounce. They are hard, but very tough and ductile, becoming soft by immersing into cold water, and their specific gravity at 67° Fahr. is 8·556. Number five is *maillechort* made at Paris, having a specific gravity of 7·18. It may be rolled out into very thin plates, and polished to a high degree. It loses about twelve per cent. when heated, and this loss renders it much whiter than before. Numbers six and seven are compounds recommended by **GERSDORFF** of Vienna, the first for forks and such like articles, and the second for such objects as require soldering. The commonest German silver is, according to Mr. **TOPPING** of London, represented by number eight. It should be used only for wire-drawing and other common purposes. If the quantity of nickel be reduced below this, the alloy will be little better than pale brass, and will tarnish rapidly. Number nine is another alloy, recommended by the same person as being a very beautiful compound, and little inferior in appearance to silver that is nearly standard. It is often preferred to the more costly compounds. The richest alloy which can be made without injuring the mechanical properties of the metal is number eleven. It is a very beautiful compound, but more difficultly prepared than the preceding, owing to its requiring a high temperature for its fusion.

An alloy called *tutenag*, and composed of 45·7 of copper, 17·4 of nickel, and 36·9 of zinc, is very serviceable, especially for casting. It is in frequent use among the Chinese. It is very fusible, but hard, and not easily rolled, and in color resembles very much the alloy *electrum*, the analysis of which is given in number nine of the foregoing table.

A small quantity of iron hardens considerably these alloys, and likewise gives a bright color; but it renders the metal more difficult to work.

In the preparation of German silver, as in the manufacture of brass, the work is performed in pots or crucibles, and much of the zinc passes off by volatilization and oxidation. By care, however, this loss may be reduced to some extent; still a large quantity escapes, which must be made up in the alloy by taking a larger proportion of zinc. It is the usual custom to have the metals arranged in alternate layers in the crucible, the lowermost and topmost being copper; charcoal powder, dust, or powdered glass are strewn upon the surface. When the metals enter into fusion, it is necessary that the contents of the pot should be stirred with a porcelain rod, in order that the compound may be rendered more homogeneous, notwithstanding that some of the zinc is wasted; but this must be anticipated by the operator, and a corresponding amount of this metal added in excess to compensate for that consumed. For this reason, three or four per cent. of it are added to the clippings and filings of German silver, when they are being fused a second time, to compensate for the loss which the metal sustains.

BRONZE.—This alloy, which is composed of copper and tin, has been frequently alluded to in the preceding part of the present article, as being the compound known to the ancients under the name of *brass*, and of which they made all their implements of war and domestic economy before iron came into general request. Independently of biblical translators, who are of opinion that by the terms brass or bronze, was meant copper, and not a compound metal, the Editor draws the inference from the searching analyses of the most ancient coins, and other metallic matters which have come within reach of modern chemists, that the isolated metal was not in general use.

As to its varied employment in the arts at the present day, bronze undoubtedly ranks below brass, but in certain of its applications it is much more eligible than the latter. The principal of these are in the making of the baser currency, in statuary, cannon and bell founding, in casting medals and telescopic mirrors, as well as in the construction of tam-tams, cymbals, and other articles, which, however, are not of common occurrence. Regarding its application in one or more of these departments, the public taste has, according to the historical records of the times, undergone three or four great changes. The first of its manifestations, and which might be said to be created by the pride and selfishness of the people, was for statues of this metal, and prevailed to an enormous degree in the time of *Alexander the Great.* Certainly, castings in it had been made from a period far anterior to the reign of that monarch; but the celebrated artist LYSIPPUS, by his discovery of the means of moulding, *et cetera*, afforded facilities in this art which were not neglected, for so abundantly were bronze statues erected afterwards, that PLINY called them the *mob of Alexander*. Huge colossi were also raised and multiplied, and it is related that MUTIANUS, the Roman consul, found three thousand bronze statues at Athens, the same number at Rhodes, and as many at Olympia and Delphi. These passed away, and a different phase of the public taste was developed in the middle ages, in the desire for enormous church bells, to proclaim from the mountain top and the secluded glen the sway of the Church. Lastly, these have comparatively given way to the application of this metal for purposes of national defence or aggression, by transforming the bronze into cannon, or other engines of war. Such may be regarded as the characteristics of the present time; and whether the next revolution will be their conversion into ploughshares, or articles equally peaceful, remains to be seen.

It might be supposed, at first sight, from the castings of the ancients, that they possessed some very expeditious and simple means of making their enormous and numerous productions in this department; but, upon closer inspection, this conclusion appears untenable; for it is demonstrated, by the analyses which have been made of some of their alloys, that they were very imperfect, arising doubtless from their want of sufficient knowledge to enable them to preserve the homogeneous nature of the fused metal, by supplying such constituents as were lost by oxidation in the prolonged fusion to which they were necessarily subjected. The same fault is observed in many of the articles of comparatively modern date, but its immediate recognition renders improvement in the art more certain and progressive.

Although copper and tin are the essential components of bronze, zinc and lead are sometimes incorporated, but generally in those cases where the alloy has not much to resist. Its properties vary, of course, with the composition, but in all cases it affords compounds which are harder and more durable, besides possessing more tenacity, than copper.

Bronze is always more fusible than copper. Its density is greater than the mean of its constituents; but this is subject to some little derangement, owing to the vesicular structure which the ingot or casting assumes at the point of solidification, by which its bulk is increased, and, of course, the real gravity of the metal reduced. Hence, to ascertain the true specific gravity of bronze, portions of the ingot should be cut off and reduced to fine powder, and weighed in this state; and the extent of the preceding error might be determined by ascertaining the apparent density in the bulk previous to the reduction to powder, and comparing it with the secondary results. The following table of a few of these alloys shows their gravity, and the difference between these and the calculated mean:—

Alloy.				
Copper.	Tin.	Observed density.	Calculated density.	Difference.
96·2	3·8	8·79	8·74	0·05
94·4	5·6	8·78	8·71	0·07
92·6	7·4	8·76	8·68	0·08
91·0	9·0	8·76	8·66	0·10
89·3	10·7	8·80	8·63	0·17
87·7	12·3	8·81	8·61	0·20
86·2	13·8	8·87	8·60	0·27
75·0	25·0	8·83	8·43	0·40
50·0	50·0	8·79	8·05	0·74

Another behavior of bronze when cast in sand moulds, more especially if they be large, is, that shortly after casting, a jet of liquid metal issues from the interior, either at the sides or at the upper surface of the metal. This has been accounted for by supposing that the first portion of the alloy which comes in contact with the walls of the mould condenses, and, in so doing, contracts to some extent, and by this means displaces the more expanded molten matter inside; and if the pressure of the metal from above is considerable, so as to prevent the ascent, it will exude laterally; but when the weight thus bearing upon it is not very great, it forms an upward current. It has been found that the metal thus eviscerated is much richer in tin than the remaining portion of alloy which has solidified at the bottom and the circumference of the object, and that in these parts also great variations are often detected, as the annexed table, from the experiments of M. DUSSAUSSOY, points out:—

		At the surface, and within six inches of the base.	At the centre, and within six inches of the base.	At the top surface.
Ingot three inches square, and thirteen in height, weighing forty pounds,	Copper,	89·09	90·63	90·54
	Tin,	11·91	9·46	9·46
		100·00	100·00	100·00
An ingot of the same dimensions moulded in sand,	Copper,	90·0	99·9	83·6
	Tin,	10·0	9·1	16·4
		100·0	100·0	100·0

It is well known that bronze, containing about eighty-five per cent. of copper and the remainder of tin, is somewhat malleable. This property can be communicated to a much greater extent, by tempering the metal like steel, but with opposite effects. Even alloys composed of proportions different from the foregoing may, by a similar treatment, be made to work under the hammer. The tempering in this case lessens the density of the metal, as also the hardness; it affects the malleability and flexibility, and sometimes renders it more tenacious, besides giving a duller tone to the sound of the alloy.

Many articles require in their preparation that the bronze should partake of some of these properties, and in this department the tempering is highly conducive to the success of the mechanical work, because, if the objects after being cast are slightly tempered, they may be made to work under the hammer, the lathe, or the press, and when thus finished, the hardness may be re-communicated by heating them.

According to DUSSAUSSOY, the alloy which best comports itself under this treatment is composed of eight equivalents of copper and one of tin. This always increases in tenacity when the ingots or objects are of some thickness, whereas, with the most part of the others, the contrary is the case. The annexed table shows the results of some experiments made upon this subject:—

		Composition of the alloy, centesimally.				
Copper,		95	90	85	80	75
Tin,		5	10	15	20	25
		100	100	100	100	100
Density before tempering,		7·92	8·08	8·46	8·67	8·57
Density after tempering,		7·89	8·00	8·35	8·52	8·31
Hardness before tempering,		100	100	100	100	100
Hardness after tempering,		99	98	96	92	91
Sample ¾ths of a line in thickness,	before tempering, tenacity,	80	66	48	50	70
	after tempering, tenacity,	100	100	100	100	100
Sample of eight lines in thickness,	before tempering, tenacity,	100	100	80	80	100
	after tempering, tenacity,	75	78	100	100	35

Other circumstances tend to modify the quality of bronze considerably, the principal of which is the liability to alter in composition during the melting, by the oxidation of the tin. Many large castings manifest this imperfection to a considerable extent, more especially if the metal required many fusions before the objects were finished. That of DESAIX in the Place Dauphiné, and the column in the Place Vendome, are noted specimens of most defective workmanship, owing to the want of knowledge in regard to the cause of the defect already mentioned.

On analysing, separately, specimens taken from the bas-reliefs of the pedestal of the latter column, from the shaft and from the capital, it was found that the first contained, centesimally, six of tin and ninety-four of copper, the second contained much less tin than the first, and in the third, the tin was found as low as 0·21. Hence it will be seen that the founder, instead of maintaining the alloy at its average composition, allowed the copper to be gradually refined, the other metal being thrown off as oxide. If the alloy be exposed to the air during the fusion, both the metals constituting it will be oxidized, but in very unequal proportions; thus, in an alloy composed of ninety-one parts of copper and nine of tin, for every part of the latter which is thrown off, there are two or three of the former, but it is evident that ultimately the mass would be deprived of all the tin. The numbers annexed, taken from the analyses of the gentlemen already quoted, show the extent of the oxidation, and the variation in gravity which took place in the sample studied. The alloy was ordnance metal, cast in sand, and contained ninety parts of copper and ten of tin.

				Composition.	
Number of fusions.	Weight of ingot in ounces.	Loss per cent.	Specific gravity.	Copper.	Tin.
1	268	1·2	8·565	90·4	9·6
2	236	1·6	8·460	90·7	9·3
3	204	2·1	8·386	91·7	8·3
4	172	2·5	8·478	92·8	7·2
5	140	2·6	8·529	93·7	6·3
6	104	3·0	8·500	95·0	5·0

In addition to the loss suffered by the oxidation, another of a more serious nature attends it, namely, the incorporation of some protoxide of the metals in the alloy, which renders it brittle, and not calculated to wear well. It is, however, easily remedied, and requires only the fusion of six or seven ingots, with the requisite quantity of tin, together with some charcoal, and, if found necessary, poling the bath as in the refining of copper. All the oxides are thus reduced, and the alloy acquires a fine grain, and no bubbles appear in any part.

Latterly, manufacturers introduce a small amount of iron into bronze in the founding, in order to ameliorate its quality; but experience has proved that this should only be employed in brass which is destined for small objects, as it gives to them hardness and tenacity, which are undistinguishable in large castings. The quantity used should never exceed about one to one and a half per cent. of iron, and it should be incorporated in the form of white or tinned sheet-iron. This is mostly done with the view of improving old bronzes, which are rather impure. Ferruginous alloy is always less fusible than ordinary bronze, and on this account is less disposed to form cavities in the mass when cast in sand moulds, because the matter immediately solidifies upon the walls of the mould, and does not allow the entrance of the air into the fluid mass, as is the case when ordinary bronze is cast under the same circumstances. In clay moulds, however, this quality is useless, because the ordinary material does not comport itself in these moulds as when they are sand. Zinc is also alloyed with bronze in certain proportions, and communicates similar results.

Lead is not an advantageous ingredient in bronze, but rather the contrary, because it is readily oxidized, and hence augments the loss in the other metals, by facilitating their combination also with oxygen; besides, it has a tendency of precipitating the copper with it towards the bottom of the casting, thus producing great inequalities if the object be large.

For many of the uses to which bronze is applied in the arts, its composition is altered; thus, for wheel boxes or sockets, the alloy contains—

	Centesimally.
Copper,	80
Tin,	18
Zinc,	2
	100

The fracture of this alloy is nearly white; it has a dry grain, and is very hard, but still may be worked. The zinc is added with the view of preventing cracks, which are apt to form in the casting, owing to the contraction of the alloy upon cooling.

Another alloy intended for a similar use, and for the collars of motion cylinders, has the following composition:—

	Centesimally.
Copper,	82
Tin,	16
Zinc,	2
	100

This is somewhat more malleable than the preceding, so that when the collar is being forced on to its place, it is less liable to break.

An alloy, when required to resist powerful friction and sudden shocks, is made of the annexed proportions, namely—

	Centesimally.
Copper,	83·0
Tin,	15·0
Zinc,	1·5
Lead,	0·5
	100·0

For pump-boxes and balls, and such articles as require to be brazed or soldered, the proportions are—

	Centesimally.
Copper,	87
Tin,	12
Antimony,	1
	100

This alloy, when broken, presents a reddish fracture, with a fine grain. It is malleable, but not sufficiently so as to answer for the material of stop-cocks, pump-valves, and the like, which are subject to receive concussions, *et cetera*, that would endanger the safety of the article, unless it were sufficiently pliant to resist them. Compositions of this nature contain—

	Centesimally.
Copper,	88
Tin,	10
Zinc,	2
	100

This alloy has a fine grain, and is capable of receiving a high polish; it has a nice red color.

Having thus far dwelt upon the general properties of bronze, it may be well here to direct attention to the various manufactures in this alloy, showing how its properties affect the qualities of the objects fabricated. Those to which especial attention will be devoted, are the manufacture of coins and medals, cannons, bells, and that preparation which, though truly a bronzing one, is designated tinning, together with a few others of minor importance.

Regarding the first of these applications much might be said, as it is necessary to have an alloy so constituted as to be able to receive a true impression, and wear well. These qualities have very often been sadly overlooked, and it not unfrequently happens that, after ten or twelve years' circulation, all traces of the impression are entirely obliterated. The ancients teach a good lesson in this particular, and the antiquarian is the only one seemingly grateful for it, although it is particularly directed to the metallurgist. It is very remarkable how the coins of centuries gone by have resisted the powerfully injurious effects of air, moisture, and other bodies acting upon them in the most favorable manner to cause their destruction; true, they have suffered to some extent, but although exposed for a period exceeding twenty centuries, their characters are not so far effaced as to render them illegible, and, therefore, useless to the antiquary. The cause of this difference is apparently the employment in later years of alloys which contain an excess of copper; these are always softer and more prone to oxidation than bronze, and hence their impressions become very readily obliterated. The resistance which the alloy would thus offer ought to be a criterion of its value; such is the case in regard to the gold and silver coins or medals which are struck off, and although the copper coinage is comparatively of little value, yet it is sufficient to induce the mints of the various nations to employ such a compound as would be the best calculated to resist the injuries which it is liable to receive. The fact that the current equivalent of goods and labor is always estimated, if it reaches to any considerable extent, in gold or silver, and that the baser coin under consideration seldom takes even an inferior part, might be taken as a set-off to the founders in bestowing that care upon it which it merits; but this, in an industrial point of view, is a mistake, and financially it will not hold good; for the facility with which it wears, involves the necessity of new coinage, where it might be unnecessary were the alloy of such a composition as to resist for a long period the influences which would tend to injure it. Bronze, however, is somewhat more difficultly worked than copper, and on this account it might be superseded by the latter metal, which gives a sharper outline of representation under the die, but the effect of the tempering on the former, lately ascertained, will subvert this, as it permits its being worked under the roller or hammer, almost with the same ease as copper itself.

The bronze employed in the mint, as well as that used in casting medals, contains a variable proportion of tin, ranging generally from seven to eleven per cent., although this has occasionally been raised from four to seventeen per cent. Sometimes zinc is used in that which is devoted to the casting of medals, the quantity being about the same as the tin, and both together making the per centage of the latter just noted. Latterly, in the mints, it is customary to cast the alloy in ingots, which are laminated by the rolling mill to the requisite degree; the separate pieces are then cut out, and the edges prepared or milled, after which the impression is stamped upon them. All this is done by machinery in a shorter time than it takes to express it, and although the means by which it is performed is very interesting, yet to digress from the chemical to the mechanical path would not be warranted.

The metal intended for medals is generally melted in small crucibles, and then cast in a mould made of sand. It is constructed of two parts or frames; the lower one, filled with the fine sand slightly moistened, is sprinkled over with ground charcoal, and the model either in wood or metal pressed down to half its thickness; the top of this is likewise covered with the powdered charcoal as before, and the superior frame pressed upon it, and secured in its place. Three small openings are formed in the sides of the frame, by laying the one end of iron or brass wire against the model, the other passing out of the frames, all of which are withdrawn as soon as the frames are secured to one another. In one of these, a small tube is inserted for the purpose of introducing the metal, and the other two serve for carrying any vapor from the interior during the drying, to which it must now be subjected. To expedite this part of the work, it would be well to use only as much material as will be sufficient to resist the action of the metal, and also it hastens the desiccation to have the exterior coating composed of coarse sand, for then the aqueous vapor escapes with greater facility. Another point of economy is to cast the model and the feeding jet in some metal which will be able to resist the pressure of the moulding frames, so as to avoid the inconvenience and injury which sometimes arise from the drawing of the wire already spoken of; in doing so, however, one moulding is sacrificed, but the advantages gained compensate for this. Although charcoal powder is mentioned as being strewed over the moist moulding frames, yet this is not the only material which may be effectually used for this purpose; finely-ground bone-ash, powdered slate, and such like, may be employed, but the first is to be preferred when it can be conveniently obtained, because, being soluble in hydrochloric acid, it can be removed by this means from the medal, and thus its cleaning is performed with facility.

The other opening by which the moisture or other vapors flow out must always be formed with the wire. Both this and the jet should be proportionate to the size of the casting, more especially the latter. The jet can be made to communicate with the model in two ways: either by the lower part in the form of a siphon, or by the upper in the usual manner. When the siphon form is used, the metal must be cast at a higher degree of heat than in the other, because of the length it has to travel before it enters the mould; and although, by filling the latter from beneath, it allows the moisture and air to escape more freely than otherwise, yet the greater heat is productive of inconveniences, by giving porous castings, which are not to be combated when the other kind of jet is preferred. Besides these mentioned, there is another difficulty to be contended with in casting the metal, and this is, that the cast has never that strict identity with the model, in dimensions and the particulars of outline, which it is necessary that it should possess. This arises from the circumstance that the metal, in the act of cooling, contracts very much, and therefore, when the casting and mould are placed adjacent to one another, a marked difference is visible; but after being submitted to the pressure of sinking the die, it becomes more apparent. It may, however, be remedied by making the mould sufficiently large to compensate for the contraction which takes place. An exterior coating of a different body to the model has been found to answer well; lead paper has been proposed, but on account of the inconvenience which it necessarily offers, it cannot be satisfactorily managed.

As a substitute, recourse is had to tinning the model, and although the coat thus deposited is very small, yet it is sufficient to make up for the contraction, and besides, it contributes to remove all the slight inequalities of its surface, which, unless prevented, would be impressed upon the casting. All these particulars being carefully noted and observed, the compound metal, which should be fused in quantities of ten or twelve pounds in crucibles, heated by preference in a small wind furnace, is poured into the moulds at such a degree of heat as will not injure their outline. This point can only be arrived at by practice, which may be assisted by the following particulars:—If the metal be too cold, it flows badly in the mould, and the casting appears pasty; if too hot, it will act upon the moisture of the sand, and disengage vapors which will give a blistered irregular surface to the object cast. When the metal is heated to its proper degree for casting, it is found coated with a layer of oxide which has a smooth even surface; if this be removed, and the metal examined, it appears of a brilliant white. If the heat be too feeble, the oxide on the surface will not be smooth, but present an uneven tarnished appearance; on the contrary, if the temperature be too powerful, the oxide enters into fusion, and appears like the metal, quite luminous.

As soon as the moulds are filled, the castings should be removed with all possible speed, in order that they may be thrown into water for the purpose of annealing; if this be neglected, and they are allowed to cool, they must be again heated to give the tempering necessary for their being worked under the die. After the impression is received, they are again heated to regain the peculiar hardness and durability of the bronze.

This terminates the work of casting medals or coin, but before they are laid aside, it is customary to give them the finish, in order to make them resemble the ancient bronzes. This is done by boiling the medals, *et cetera*, in a solution of chloride of ammonium and acetate of copper. A film of oxide of copper is thus deposited upon their surface, the color of which is more or less intense, according to its thickness. If the composition of the medal be rich in tin, this process is not very successfully accomplished; but should zinc enter into it as a constituent, it can be very well done by rubbing the surface with a powder prepared of sand, and a copper salt mixed. Sometimes this is prepared by taking the following proportions of the ingredients named as under, digesting the whole in a bath of dilute nitric acid, and applying the solution with a brush. The mixture for antique bronze is—

Ordinary vinegar,......................	0·90
Chloride of ammonium,...................	0·09
Powdered green,.........................	0·01
	1·00

For Florentine bronze the ingredients are—

Alcohol,................................	0·80
Red lead,...............................	0·20
	1·00

Digested as above described in dilute acid before being applied.

The following table shows the standard weights, value, *et cetera*, of the copper coins of Great Britain:—

COPPER COINS; STANDARD WEIGHTS; REMEDY; LEGAL TENDER, ET CETERA.

Denomination of coin.	No. of pieces in the pound avoirdupois.	Weight of each piece.		Value of one pound.	No. of pieces in a ton.	Value of a ton.	Remedy by indenture.	Legal tender.	Date of proclamations fixing the amount of legal tender.	Where current.
		In drs. avoir.	In grains troy.							
Pence,................	24	10·66	291·66	2s.	53·760	£224	1/40 or six drachms, and 4/10 avoirdupois, equal to 175 troy grs. per pound avoirdupois.	12d.	14th Nov. 1821, and 30th Jan. 1826.	United Kingdom and B. Colonies.
Halfpence,............	48	5·33	145·83	2	107·520	224		6		
Farthings,............	96	2·66	72·91	2	215·040	224		6		
Half do.,.............	192	1·33	36·45	2	430·080	224		—	—	Ceylon.
One-tenth of a penny,.	240	1·06	29·16	2	537·600	224		—	—	Ionian Isles.
One-third of a farthing,	288	0·88	24·30	2	645·120	224		—	—	Malta.
One-fourth do.,.......	384	0·66	18·22	2	860·160	224		—	—	Ceylon.

The moneyers deliver the coin at the office of the mint in bags, containing half a hundredweight, the value of which is five pounds twelve shillings; thence it is given out to the public in quantities weighing fifty pounds, or five pounds sterling.

ORDNANCE OR CANNON METAL.—The manufacture of cannon is one which absorbs a considerable quantity of bronze, although its amount bears only a wide proportion to the number of these destructive implements cast of late years. The alloy employed is formed of eighty-eight to ninety parts of copper and twelve to ten of tin, and from which standard the founder very seldom deviates, although the constituents must be varied according to the size and nature of the casting. It is absolutely necessary that the metals should be quite pure, for the smallest admixture of sulphur, lead, iron, or arsenic, would cause serious injury, and probably render the cannon useless. This will be evident from a short consideration of the nature of the compounds which would be thus constituted, and the resistance they have to overcome when the cannons are brought into active service. It has been already shown, that lead, when combined with copper and tin, gives rise to a soft alloy greatly deficient in tenacity; this metal is liable to enter into fusion at the temperature developed by the explosion of the charge in the cannon, and to occasion inequalities which destroy, in a great measure, the efficacy of the machine. Again, if sulphur, arsenic, *et cetera*, be present, they render the alloy brittle, and consequently unable to withstand the shock of the discharge with impunity.

The absence of these matters, however, does not insure the freedom from defects, which are often very serious, and arise as well from over-hardness and want of tenacity in the alloy, as from the sources noticed. It is well known that, by augmenting the quantity of the tin, the hardness of the alloy is increased, though at the same time the retentiveness is more or less diminished as the weight of the alloyed metal exceeds a certain limit; it happens, however, that although the two ingredients might be proportioned in the best possible way, yet, during the casting, the heavier metals gravitate to the bottom, giving rise to a more fusible compound in the superior part, which necessarily must contain more tin than it would do were the mixture homogeneous. The parting of the metals in this way occasions serious defects in the cannons, for it not unfrequently happens that portions of them, which contain an excess of tin, and which are, consequently, easily melted, assimilate the sulphur in the gunpowder at the point of explosion, and give rise to cavities of sulphide of tin which quickly occasions incrustations. Indeed, the most serious defects arise from the change which the metal undergoes in the mould, and which is sometimes apparently unaccountable, as two castings from the same charge are often found to possess the most opposite qualities.

But this cause of defect is not entirely without a remedy at the hands of the experienced manager; by cooling the metal to a certain point before allowing it to fall into the mould, and effecting the cooling by a certain period, the parting of the metals is to some extent prevented.

Experience has proved that one alloy will not answer equally well for all the pieces which may be cast. For eight-pounders, or thereabouts, that which is best adapted is made from ninety-two and a half parts of copper, and seven and a half of tin, instead of the composition already given, and which seems to be best adapted for the twelve-pounders, *et cetera*. The practical details of the casting of cannon, to which attention will be directed, are seemingly simple at first sight; yet to overcome the sources of defects which are only partially glanced at in the foregoing, and to be able to regulate the various phenomena which are developed in the different stages of the work, requires no small share of theoretical knowledge of the materials, blended with considerable practical observation and experience. It is not the intention of the Editor, however, to enter at length upon the various operations connected with the manufacture of cannons, but only to describe such processes as are indispensable to give the reader an idea of the business, and explain such parts as are influenced more or less by chemical laws.

The exclusive use of new metals in practice would not be very convenient, notwithstanding that some facilities might be offered by them, which, under ordinary circumstances, cannot be taken advantage of. Old cannons, the matter from previous castings, and the scales and debris of the foundry, constitute the great bulk of the charge. Considerable loss is sustained in this manufacture, and a great overplus of metal; this, however, is for the most part recoverable, yet it requires some calculation to be able to perform the operations effectually. It is laid down as a rule, that to obtain a casting of one hundred pounds weight, no less than two hundred and twenty pounds of material must be employed. It is disposed of in the following manner:—

Weight of casting,..............	100	pounds.
Loss of bronze in the scoria,......	12·5	„
Bronze wasted in the debris,......	107·5	„
Bronze employed, ...	220	„

The loss of metal and temporary waste being so great, it is evident considerable practice must be brought to influence the proper management of the work. For greater facility, rules have been laid down whereby the quantity of material required to be operated upon in order to produce a certain weight of castings, may be ascertained by comparison. It is stated that, in each charge, one-tenth of its weight of new or ingot copper should be used, and that the tin in the shape of ingots should form about fifteen per cent. of this quantity.

The subjoined numbers express the proportions which are to be used in the constitution of—

2200	pounds of casting, namely,
488	pounds of ingot copper,
73	pounds of ingot tin,
1769	pounds of old pieces of bronze,
2556	pounds of bronze in the waste attending the manufacture.
4886	pounds; total weight of the mixture employed.

The real loss attending the manufacture under ordinary supervision, and with due care, does not exceed ten per cent., and rarely indeed amounts to this, more frequently bordering on six. It is evident from this that the furnace must not be overlooked in its erection, and that it must be of such capacity as will work the increased proportion of metal where large castings are made; but this will be subsequently referred to.

The following table from **Dumas** shows the proportions which have been followed in the foundry at Toulouse for the manufacture of cannons:—

	Siege guns.		Field guns.		Campaign guns.		Howitzers.		Mortars.	
Calibre,...........................	24	16	12	8	12	8	24	6	10	8
	pounds	pounds.	pounds.	pounds.	pounds.	pounds.	pounds.	pounds.	pounds.	pounds
Weight of furnace charge,..............	13481	9812	7894	5336	5512	3748	4013	5556	5567	2324
Weight of casting,....................	8291	5821	4454	3153	2719	1883	3488	4932	5115	1883
Weight of excess of metal used in casting,	3528	2712	2359	1356	2159	1356	—	—	—	—
Weight of waste in channels, &c., ...	330	320	309	298	309	298	298	309	309	309
Probable loss,..........................	1332	959	772	529	325	211	227	315	143	132
Probable centesimal loss,..............	9·8	9·7	9·7	9·9	5·6	5·6	5·6	5·6	5·6	5·7

Cornish and Banca tin are preferred, being more generally free from lead. Sometimes the manufacturer is constrained to employ old tin, which usually contains a large proportion of lead; but it is necessary that it should undergo a process of refining before it can be incorporated with the other constituents of cannon. This is done in a manner analogous to that described for separating copper and silver, and is based upon the greater fusibility of an alloy of lead and tin, than of the latter alone. By gently heating the metal in a reverberatory furnace, the more fusible alloy of lead and tin will very quickly begin to flow, leaving the most part of the latter metal behind comparatively pure, but not so much so as to guarantee its employment in the manufacture under consideration; hence it has to be submitted to one or other of the usual methods for depriving it of traces of lead.

The materials being at hand and ready for fusion, the mould should be prepared so as to receive the metal when melted, to give it the proper shape. Much depends upon the proper construction of the moulds in getting the pieces free from defect. They should have sufficient solidity to prevent the melted metal altering them, and the air and other gases which are contained in them, or developed by the heated medium, should have ready means of egress; otherwise, if confined, they will either endanger the safety of the mould by their expansion, or render the casting vesicular and imperfect. The material employed is of three kinds; namely, clay, sand, and shells; but the last is scarcely ever used, as it offers much inconvenience. With the first two, in which the mouldings are more commonly prepared, a quantity of brick-dust, cow hair, and horse dung are incorporated, to give them tenacity, so that they may be able to resist the metal. Care should be taken that no lime or silicious oxide of iron enters into this mixture; because the first would cause the evolution of gaseous matters when the liquid metal comes in contact with it, and the other would enter into fusion; the defect of blistering would follow from the former, and loss of true outline would be the result of the latter.

The method of procedure is to grind the clay, or temper it very fine with the aid of moisture, and then mix four parts of this with one of dung, leaving the matter to rest for eight days or thereabouts. This loam is macerated with three-fourths of its weight of sand, to which about a sixth of hair has been added. Another mixture is composed of clay, two parts by measure—sand one, dung a half, and hair half a part, the whole being well commingled. In the preparation of this mixture, however, various proportions are taken by different parties, all of which may be suitable in certain cases.

Fine sand, mixed with gelatine or glue, is also used to communicate an even surface to the mould before depositing the wax upon it. This article is usually obtained by burning tanners' waste, and washing the ashes with water to remove alkalinity. The more distinct parts of the mould are constructed of a mixture of two parts of yellow wax and one of resin. After they are made in the usual manner, they are dried, so as to be ready to receive the melted metal.

Reverberatory furnaces are resorted to for making the alloy, of which two forms are in use. One of these has the hearth circular, while the other is of the elliptical shape. Wood is generally burned in those with a circular hearth, and coal in the other variety. Artificial blasts are not employed in either case; but the draught is increased as much as is required to generate the proper degree of heat, without admitting any oxygenous gases into the furnace, which would tend to scorify the metals. On this account, the fire is situated in the arch of the furnace, and, as a precautionary means, the fuel is always kept in a thick stratum upon the grate, to deoxidize the air passing in for supplying the combustion. Some regard the furnaces with circular hearths as being more economical, on the ground that they hold more matter, and present a less surface than the other to the flame, and, therefore, the charge in them is less liable to oxidation than if the hearth were elliptical; also, that they produce a more cohesive bronze. On the contrary, it is acknowledged that the other effects the fusion of the charge more rapidly, and affords facilities for rabbling and poling, of which advantage cannot be taken in the foregoing; likewise, that it produces a more homogeneous alloy, and that the consumption of fuel is much less than in the round furnaces. When, however, much sulphurous matter is contained in the fuel, serious injury is caused thereby, inasmuch as it gives rise to the formation of sulphides of either of the metals, which render the alloy brittle and inelastic.

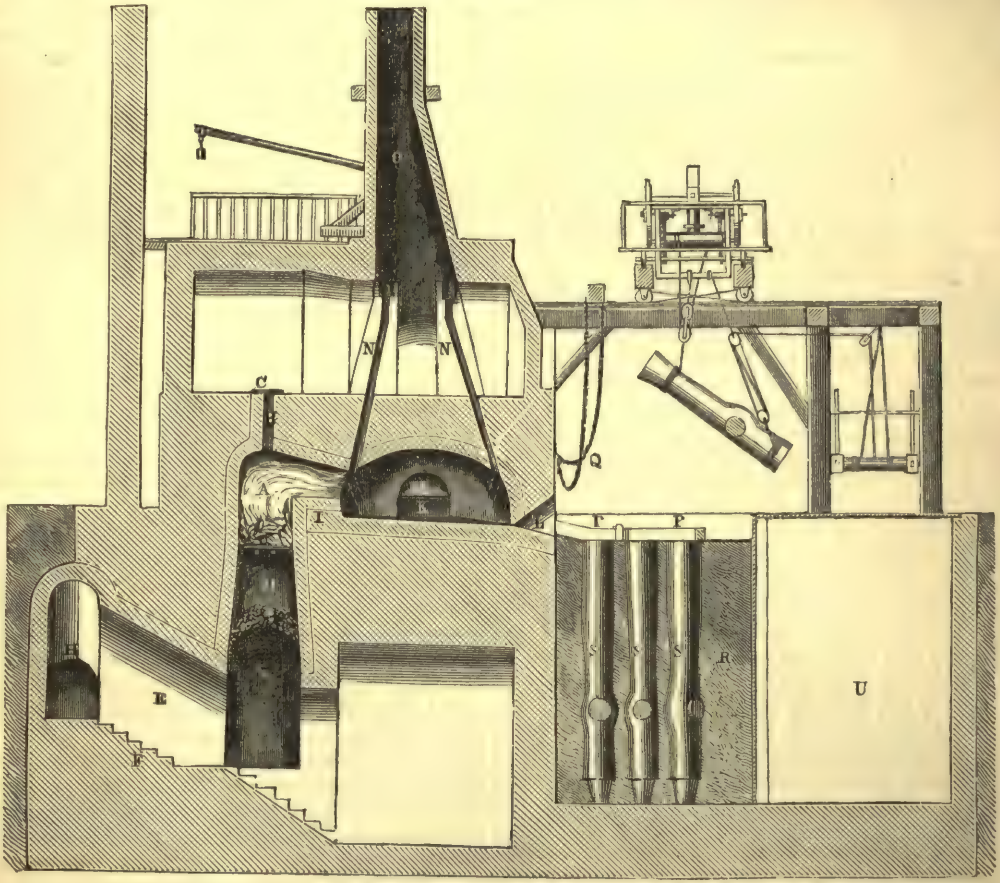
Figs. 345 and 346 represent one of the furnaces in use in the ordnance foundry at Toulouse. A is the fire-grate; B, the gullet leading from the door, C, through which the billets of wood are introduced. D is the chamber in which the cinders and ashes fall. This chamber is under the body of the furnace, and is approached by an inclined plane, E, and staircase, F. G is the channel through which air is admitted to the fire for maintaining the combustion of the fuel. Other galleries communicate with this, in order that a sufficient supply may be afforded, such as that shown at H; but, in constructing these, it is necessary to exercise care that they do not intersect and destroy one another's effect; also, that they open in the direction in which the wind blows most frequently, and that the orifice be capacious enough for supplying the necessary volume of air. The fire-bridge is seen at I, the hearth or bed of the furnace at K, and the outlet by which the fused metal is drawn out to the channels whence the moulds, S S, are filled, is shown at L. The working opening is seen at M, another of the same kind being at the opposite side, and both closed by plated iron doors, and furnished with swinging bars, to facilitate the working of the charge. N N are the flues leading from the hearth to the chimney, O. P P are the channels through which the fluid metal flows into the moulds. Q is a chain, by the aid of which the iron plug and other means which secure the opening, L, are removed. The moat in which the moulds are imbedded is represented by R, a similar place, U, being destined to receive the clay when they are being drawn. This is accomplished by a winch erected upon parallel bars, and moving on an iron railway, all of which are represented in the drawing.

According to the extent of the foundry and the size of the castings, several furnaces, of various capacities, are requisite, the principal ones being destined for making the bronze, and the lesser for smelting the refuse matter of the manufactory, or purifying some of the substances which are to be operated upon. The three parts of the furnace which require especial attention, are the fire, the hearth, and the chimney. With regard to the first of these, as already mentioned, the principal fact, which deserves to be particularly noted, is the regulation of the draught. One of the reasons for constructing the fire-door in the arch of the furnace is, that it may not interfere with the current of air passing through, which it would not fail to do if constructed at the side, as is customary in reverberatories. The ashpit is entirely enclosed with the same view, in order that the hot cinders which fall through the grate may not rarefy the current of air rushing to the fire, and cause a deficiency, by this means, from the actual volume necessary to maintain the proper temperature. To render this more effectual, it should be rather spacious. The galleries, in like manner, should contract as they approach the fire, so that the current may be delivered as dense as possible.

The interior of the furnace in which the operation of smelting is conducted, is composed of two planes, inclined towards the middle, thus offering, by their intersection, a cavity leading to the outlet through which the liquid alloy is drawn off when requisite. During the fusion, the metal is watched and treated, with the necessary attention, through the doors already mentioned. A variable position and construction is given to the flues, according to the size of the furnace; their superior end borders upon the chimney, and their lower extremity is sloped, and partly dips into the molten bath, so that the flame has to traverse the whole surface of the hearth before its exit. It is needless to say, that the entire surface of the interior of the furnace should be made of the very best refractory bricks, set in a cement which will likewise effectually resist the action of the fire. For greater security, a coat of refractory lute is put on the interior superficies.

When the furnace is newly erected, or the luting is renewed, it retains a great deal of moisture, which necessarily should be expelled before operating upon the metals, otherwise, if allowed to remain, it would act injuriously upon the structure, causing it to crack and break in various parts. To effect the desiccation, the interior is filled with bricks, by piling them upon the hearth in such an open manner, that the flame and heated vapors from the fire will easily permeate the mass. The doors are closed by a few firebricks cemented together by mortar, and the fire, which may be of coal, wood, or charcoal, according to the kind of furnace, is then lighted. At first, the heat should be very gentle, and, as the excess of aqueous vapors is expelled, it may be gradually increased during eight or ten days, about which time it arrives at a white heat, which should be maintained for two days longer, or thereabouts. At the termination of this period, it may be safely assumed that the whole is thoroughly baked. All the doors and other orifices are then opened, and the structure allowed to cool gradually. Sometimes it is necessary to repair the furnace by such a coating. This should be foreseen in its erection, and sufficient room left for the purpose. In the latter instance, the baking need not be prolonged beyond three or four days.

Fig. 345.

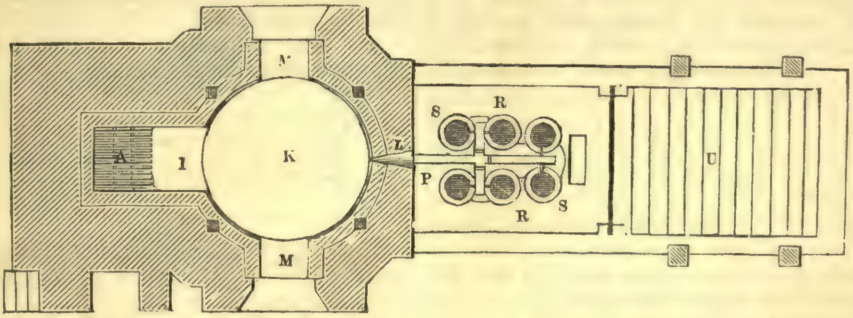


The charging of the furnace follows the removal of the bricks from the interior, by introducing, first, the ingots of copper, the fragments of old cannon, and other cupreous matters. As soon as these are liquefied, the remainder necessary to make up the total, in the shape of scales and turnings from the hammer and lathe, together with the requisite weight of tin, is added. Before introducing these matters, however, it is customary to coat the hearth and the walls with moist cinders, in order to prevent contact of the bronze with the bottom and sides, to which, if this were neglected, it is apt to adhere. The mouth of the outlet is likewise closed with an iron plug, coated with loam, so as to fit more accurately the orifice. In arranging the charge on the bed of the furnace, the larger pieces are placed in such a position that they will receive most heat. Care should likewise be taken that the mouths of the flues are not blocked up. On the contrary, these should be left as free to act as possible; because the briskness of the combustion is dependent, in a great measure, upon them. On the Continent, the furnaces of larger dimensions are generally heated with wood, oak or beech being used according as the country will supply it.

During the first few hours of the firing, the heat is retained at a very moderate degree, so as to permit the gradual development of aqueous vapors, *et cetera.* When the sole becomes heated, the fire is urged more strongly, and the metal, which hitherto manifested no signs of its action, begins to assume an incipient redness. The flame, which also appeared dull and scarcely extended to the vent-holes or flues, at this time becomes brighter and more enlarged, so that it rises to their upper end. By maintaining this temperature the metal reaches a white heat, and very soon begins to melt in part, and so continues, till, at the end of seven or eight hours, it is entirely liquefied.

In the course of the operation, it is observed that the bronze which forms part of the charge, before it becomes fluid, appears incandescent, the tin oozes from all the pores in drops, which unite and stream to the hollow of the hearth, carrying only a small portion of copper with them in combination. The operator takes care that all the matter is perfectly liquefied, by stirring in any particles which might remain at the sides and bottom of the molten bath. When he is satisfied that all is melted, he thrusts a long pole of birch wood into the mass, and stirs it about just as in the refining of copper. This causes a violent seething, and brings both the metals into more intimate contact, thus insuring their more perfect combination than if they were left unmolested. The bath is likewise rendered more fluid on account of the ebullition raising fresh metal to the surface, where it meets with greater heat; and, unless the action of the pole be prolonged, the inferior layers would not be sufficiently liquid, because the superior one, being more expanded on account of its contact with the high temperature of the fire, is specifically lighter; it would preserve itself at the surface, unless the mechanical action of boiling instituted currents which would force the matter at the bottom to the surface to receive an equal amount of heat.

Fig. 346.



When the whole is in perfect fusion, the temperature being very elevated, the workman skims carefully the scoria which has risen to the surface during the poling. The heat of the fire is still maintained by the repeated addition of fresh fuel. The rabbling, poling, and skimming engage the whole attention as long as scoriæ are thrown off, and when these are for the most part removed, the fire being still urged to its highest limit, the tin necessary to make up the proper composition of the bronze is projected into the bath in the form of small ingots, to facilitate its rapid distribution throughout the mass. During this time, and successively to the period of casting, the fire and the poling are made to exert their utmost influence in keeping the molten mass as liquid and as homogeneous as possible.

To determine the moment most suitable for running off the fluid metal is a very critical point, and one that requires much skill and practice. Generally, it is raised to the highest possible temperature under the circumstances, and it is thought that the more elevated the heat is the better; but even this, it is reasonable to suppose, will have its limit. When the metal is nearly ready, the workman finds that the spar of wood with which he effects the poling will feel light in his hand. It can be thrust with facility into the bath, and its end will glide freely upon the bottom of the furnace. When withdrawn it retains very little metal, the chief portion falling off in small drops. The sound of the agitated matter is very clear. It may readily be thrown into numerous undulations, which as quickly subside. Fragments of lighted charcoal, which float upon the mass, move about very rapidly, especially towards the bridge of the furnace. Whenever a fresh supply of wood is thrown upon the fire, it does not cause a disengagement of gases from the bath, but the flame which escapes by all the flues possesses a brilliant whiteness.

Preparations for the castings are being made, five or six hours previous to the time in which this is to take place. The channel by which the fluid metal flows to the moulds, is coated with loam and baked, by attacking it first with a fire of wood, and afterwards with one of charcoal or coke. The moulds are to be partly uncovered, so as to permit the escape of moisture more freely. These and the canal attached are carefully brushed, so as to remove all dust and extraneous particles of matter.

The iron plug which secured the outlet is then removed by appropriate means, and the metal allowed to flow out into receptacles in the channel, whence it is permitted to run into the moulds in succession till they are filled. During this part of the work, much aqueous vapor and gases are disengaged by the superheated metal coming in contact with the matter of the mould. They cause great inconvenience and injury to the casting. The development of gases may be prevented to some extent, by taking care that no moisture can reach the mould by infiltration, and also by deferring the casting whilst the metal is too hot. When the jet appears of a bluish color, the material is highly fluid; but when it is bordering upon the point of congealing, it assumes a violet tint, arising from an envelope of a yellowish-red, and is owing to a part of the metal solidifying. The vapors already alluded to are apt to cause irregularities in the casting, if these were not prevented by pouring more metal into the inlets, and keeping them quite full, to have the defects carried off, as much as possible, from the piece. It is customary, likewise, to throw some charcoal upon them, to keep them in a fluid state as long as any disengagement takes place, so that the metal in them may supply any vacancy caused, either by the evolution of gas, or the contraction during the cooling. After the metal has sufficiently congealed, the partitions of the channel are removed, and likewise the brickwork and other appendages which were employed as means of security in the moulding, and, after two or three hours, the clay surrounding the casting at the top may be taken away, either wholly or in part. At the end of forty-eight hours or so, according to the size of the objects cast, they may be drawn, the earth and other extraneous matters being previously removed to the adjoining compartment. Owing to the pressure which is exerted upon the moulds, much metal percolates them. This is afterwards recovered by smelting those parts in which it is contained in a small furnace devoted to this purpose. The various other products of the channels, and the excess of material appended to the objects, are subsequently used up with another charge.

The cannons are next treated by mechanical agency to give them a smooth exterior, and then bored in the usual way, and finally proved by various tests.

BELL-METAL.—Great analogy exists between the casting of cannons and the founding of bells; and it may be said that the idea of the former has been borrowed from the latter, which has preceded it in point of time. Generally, greater permanency must be given to all the requisites necessary for the founding of cannon, than to those which the bell-founder employs, because the castings of the latter are more variable in their dimensions. This was more especially the case at some distant period, when the manufacture of bells was an amateur performance, and the furnace and moulds had to be only temporary. But now, owing to the facility of conveyance, the manufacture has become permanent, and from the general increase of knowledge in modern times, the improvement in the art is considerable. The standard composition of bells is taken at seventy-eight of copper and twenty-two parts of tin, the latter being sometimes increased to compensate for the loss by oxidation. Generally, however, the founder takes—

	Centesimally.
Copper,	77
Tin,	21
Antimony,	2
	100

Such is the composition of *cymbals* and *tam-tams*, the specific gravity of which is 8·815. Although the constitution of the latter has been shown, by various analyses, to be invariably composed of the above proportion, yet the former are subject to great variation, not only in the proportion of the copper and tin, but likewise in the admixture of other metals, such as lead and zinc. These metals, indeed, tend to injure the quality of the article; still, as it can be made of the requisite tone, and as by their use the manufacture becomes less expensive, it is customary, on every occasion, to employ them.

The following analysis of English bell-metal by THOMSON shows the composition:—

	Centesimally.
Copper,	80·0
Tin,	10·1
Zinc,	5·6
Lead,	4·3
	100·0

Undoubtedly, bells constituted of an alloy into which twenty to twenty-two per cent. of tin enter, are better and more sonorous than such as have the composition according to the foregoing analysis. Besides the lead and zinc, a quantity of antimony and bismuth are sometimes introduced, in order to give a more crystalline grain to the metal, but also with the view of communicating a certain tone to the bells.

A great requisite in the alloy is ready fusibility, to communicate which, the addition of some metals, such as those just mentioned, is made. It rarely happens that new materials are entirely used in preparing the bell-metal. Like the manufactures described in the foregoing, old brasses and tins are worked in large quantities. The composition of these should, however, be known, so that the mean of the alloy be such as will yield a bell of the required quality.

The moulds in which the metal is cast are constructed in much the same way as those of cannon, and the furnace employed for the fusion has also the same form, only that the temperature required need not be so elevated. In the preparation of the alloy, the whole of the tin is not put in at the beginning, about one-third being reserved for addition when the whole of the bath is in perfect fusion. About one-tenth more than the weight which is destined for the bell should be submitted to the furnace, this quantity being expended in waste and scorification during the process. The tongue or clapper of the bell is usually of iron, suspended in the line of the centre of gravity, from a ring in the head, by a thong of horse leather, or a rod of the same metal. Its length ought to be such as to strike the bell when swung near the verge, as then its effect will be greater than if the concussion took place further up.

The bells of clocks and those in domestic use are generally of the same composition as the large articles just described, although the proportion is somewhat varied, the tin being still further substituted by zinc.

CYMBAL AND TAM-TAM METAL.—As already pointed out, these are prepared with an alloy, varying from seventy-eight to eighty of copper, and twenty to twenty-two of tin. Newly cast, the alloy of tam-tams is of a greyish-white color, having a fine close grain. It is very brittle, and not so fusible as some of the alloys used in bell-founding, though more so than ordnance metal. Much difficulty had been experienced in forming the tam-tams of this bronze, on account of its great brittleness; but the knowledge of the effect of the tempering upon it has remedied this inconvenience, and given the manufacturer power to prepare his articles so as to resist all the shocks to which they are exposed. Having fused the alloy, it is cast into moulds. As soon as well congealed, they are withdrawn and introduced into a furnace, where they are raised to a cherry-red heat. They are then inserted between iron discs and plunged into water, and allowed to cool. After which they are withdrawn, only very slightly deformed, and so tenacious that they may be worked under the hammer. This property, which was discovered by D'ARCET, has, as already seen in regard to coins and medals, been of considerable service in other branches, such as in the manufacture of ship nails, of mortars, *et cetera*, and likewise for dishes and other household utensils used in hotels and large establishments. In the latter case the articles are coated with tin, so as to render their employment secure from danger. This can be renovated, whenever it is required, by immersing the objects in a solution of cream of tartar and tin. The latter metal will be deposited, more especially upon those parts which are exposed. If the alloy contained a little zinc, this deposition will become more perfect, as the latter will be more easily dissolved by the acids, and a corresponding quantity of tin will be precipitated.

TELESCOPE OR SPECULUM METAL.—This is another alloy of copper and tin in variable proportions, but the standard upon which it has been founded is the following:—

Copper,	66·6
Tin,	33·4
	100·0

It has a steel-white color, is very hard, brittle, and takes a high polish; it is employed largely in the construction of mirrors for telescopic and other purposes.

Before closing the subject of alloys of copper, it may be well to refer briefly to the tinning process, by which a true alloy is deposited upon cupreous surfaces. It essentially consists in forming a thin coating of pure tin, or of a mixed metal composed of the latter with lead or iron, upon the copper. The mode of operating is to heat the vessel to the fusing point of the substance which is to form the coating, excluding the air to prevent oxidation, and by agitation to bring the surface of the two metals into contact. Under these circumstances combination will take place, provided no other matter intervenes; but as it generally happens that manufactured copper becomes coated with a thin film of oxide during its cooling, the removal of this becomes an indispensable preliminary to the operation.

PROUST has made several experiments upon this subject, in order to determine the extent of the loss which the copper sustains by the clearing or brightening, he took five copper plates, of one square foot superficies, and after careful manipulation, found their loss to be such as is expressed in the annexed table from DUMAS:—

The first plate lost	288	grains.
" second "	350	"
" third "	355	"
" fourth "	360	"
" fifth "	393	"
Mean loss,	349	"

Several means are resorted to for deoxidizing the surface of the objects which are to be tinned, or rather for removing the slight covering of oxide which more or less tarnishes the surface, and prevents the adherence of the tin. Sulphuric acid is one of these, but the most frequently used is chloride of ammonium. The surface of the plate or vessel is sprinkled with this salt in powder, heat is then applied, and the attendant, by continued and brisk rubbing, extends over all the parts the action of the powder. By the effect of the heat, the volatile salt is first dissolved, and ultimately volatilized; but while in the former state, it deoxidizes the coating on the surface in part, and causes a further portion to be converted into chloride of copper, which can be removed in the rubbing, thus leaving the superficies bright and untarnished. The heat being still maintained, a quantity of tin is laid upon the bright part and kept melted, whilst the operator, with his pad or cork, rubs it all over more or less rapidly; this operation is continued till it is judged that the combination is perfect. During the friction, care must be taken to maintain the surface as equalized as possible, and to rub off any excess of tin from parts which might contain it. In order that some data might be at hand, PROUST determined the gain of the plates already mentioned by the process of tinning. The following are his results:—

Pan one square foot superficies, required	140	grains of tin.
First plate,	144	"
Second "	178	"
Third "	200	"
Fourth "	208	"
Fifth "	230	"
Mean,	183	"

From these numbers it will be seen that the least quantity taken up per square inch is one grain, but that this may be increased till it reaches so high as a grain and five-eighths, which is the largest amount in the table. It must be evident, however, that all the excess is not in actual combination with the copper, as it can rarely, in the time devoted to the operation, penetrate so far as to require the larger proportion of tin, not only that mentioned in the above table, but the far greater quantities used in the hands of some workmen. The fact is, that the metal is in an imperfect state of fusion, and, consequently, solidifies on the surface of the plate in a thick layer, or else it is allowed to adhere to parts which have already been tinned through inadvertence or want of skill.

A very easy and effective remedy, however, can be used in this case, namely, the maintaining of a temperature sufficient to fuse the tin, and pressing more or less on the parts with the pad; the excess of material will by these means flow off with facility, as it is uncombined, whilst that portion which has been alloyed will remain unaffected. Should an excess of tin be permitted to rest upon the surface, it is against the interest of the tradesman, neither does the consumer gain anything by it, as upon the first application of an elevated temperature it will melt off. Indeed, at best, the tinning applied to vessels in domestic use is not very durable, unless the body of the article is so thin that there will be a true alloy formed throughout, such as the tin sheet of commerce. Several causes concur in rendering the coating very easy of removal from the surface of such culinary vessels as are in almost daily request. The principal of these are the oxidizing effect of the air, the mechanical friction to which they are subjected in cleansing, and the solvent action of the alimentitious substances prepared in them, together with the exposure occasionally to higher temperatures than that of boiling water when fatty matters are being operated upon.

Tinning made with the pure metal has a silvery appearance, but whenever it becomes tarnished, it takes a yellowish cast. Regarding the portion of this metal which is removed by the acid bodies of the food prepared in them, it should be remarked that it is comparatively very minute, and beyond the reach of injuring the constitution. However, cupreous vessels tinned interiorly, ought to be kept as much as possible free from such bodies as would have a solvent action upon them.

Sometimes an alloy of tin and lead is employed in coating metallic vessels or plates, instead of pure tin. The proportion of lead is usually from one-fourth to one-third; but in some instances it forms as much as one-half of the whole weight. When the latter is employed, it can be detected with a little experience by the bluish appearance which it invariably presents. Vessels are coated in the same way as that already pointed out; but with greater facility, owing to the lower temperature required to fuse the alloy—about 338° Fahr.—and the freedom with which it floats all over the surface. The quantity of this alloy which is required to coat a given space, is not so large as if pure tin were taken: the amount seldom exceeds one grain to the square inch. When used to coat vessels in culinary use, it becomes a question of importance whether the alimentary substances prepared in them would become impregnated with lead, and therefore dangerous to health. Proust has examined this subject with care, and it may be well to submit his conclusions to the reader. He makes a calculation upon the quantity of the alloy which is required to coat a pan of one square foot superficies, it being composed of tin and lead in the proportion of two of the former to one of the latter. Allowing that the utensil would permit of its being daily used for forty-five days without requiring its coating to be renewed, and that the loss which it would have sustained during this period amounted to seventy-two grains, he calculates that the proportion of lead would be equal to twenty-four grains, or a little more than half a grain per day; and if the quantity of food which has been prepared in it be calculated as sufficient for five persons, who, to suppose the worst, consume the whole of the injurious ingredient, each of them would take about one-tenth of a grain of metallic lead per day. This amount, if actually taken, would indeed be cause enough to prove fatal to most people; and even a centesimal part of the same has, to the Editor's knowledge, produced serious derangement to the health of families who have been accustomed to drink water containing a very small decimal of lead per gallon. Proust, however, with whom Dumas concurs, makes this a supposition, and is far from admitting that this weight of lead would be taken into the system daily from the source in question, more especially if attention be paid to the following facts, namely—

Firstly, That the vessels should never be allowed to be stripped of all the coating before they are newly tinned.

Secondly, That the principal portion of the tinning is removed in the scouring or rubbing to which the vessel is subjected in the cleaning.

Thirdly, That instead of metallic ladles or spoons being employed in the preparation and confection of food, wooden ones be substituted, by which the danger of detaching particles of the alloy by the friction of the former would be avoided; and

Fourthly, That when acid bodies are heated in them the tin only is dissolved, the lead being left intact. To prove the latter, Proust subjected vessels coated with the following alloys to different processes:—

The first	was	coated with	pure tin.	
„ second	„	„	95 of tin	and 5 of lead.
„ third	„	„	10 „	90 „
„ fourth	„	„	15 „	85 „
„ fifth	„	„	20 „	80 „
„ sixth	„	„	25 „	75 „
„ seventh	„	„	30 „	70 „
„ eighth	„	„	50 „	50 „
„ ninth	„	„	pure lead.	

Upon boiling strong vinegar in the first eight of these, till reduced to a quarter of its volume, it was found that considerable quantities of tin had been dissolved out, but no trace of lead could be detected. Sometimes particles were observed on the bottom and sides of the vessel, which upon examination proved to be metallic lead; they gave a plumbous appearance to the surface, and this is more easily recognised, according as the composition is more or less rich in this metal. Their presence is supposed to be occasioned by the reduction of a lead salt by the tin in the alloy. The lead coating is easily distinguished by its bluish-white dull appearance, and, therefore, need not be further dwelt upon. Preference should always be given to pure tin, but sometimes, when the form of the vessel requires a more fluid metal, so that the whole may be covered over thoroughly, an alloy of tin and lead must be used, and the best proportion for this application would be three parts of tin to one of lead.

In order to prevent oxidation of the metals, it is customary to keep the surface covered with a little resin, or a mixture of resin and wax; the chloride of ammonium which is spread upon the plates, serves the same end when they are being tinned.

Another method discovered by Biberel is such as will be likely to arrest the attention of many engaged in this trade, as it offers peculiar advantages which render it more eligible than those already mentioned.

A compound of tin and iron is employed, the proportion of the latter varying, according to the necessity of the case, up to one of iron and six of tin.

This compound is more difficultly fused than the alloy of tin and lead, or pure tin, and, consequently, the vessels which are to be coated with it must be subjected to a heat approaching low redness, in order that it may be enabled to retain it in the melted state, whilst the operator spreads it upon the surface. The method of performing this is by applying the end of the ingot to the heated plate, and rubbing it briskly and with some pressure. When the whole has been coated, the vessel is allowed to cool, and any excess or inequality in the tinning is removed by a scraper.

The superiority of this as a coating for copper vessels, arises from its tenacity and the comparatively high degree of heat required to melt it. The latter quality increases with the quantity of iron contained in the substance, and the reverse is the case when the proportion is lessened.

In the humid way, copper cannot be coated with tin, although it quickly receives the metal in this state if it be alloyed with zinc. Tinsel and other light articles of brass are tinned in the moist state. The course followed is to deposit a layer of cream of tartar—bitartrate of potassa—upon the bottom of a flat dish or vessel, placing thereon a layer of grain or powdered tin, and upon this a bed of the turnings. When the vessel is filled thus with cream of tartar, tin, and the brass, lies of wine or beer are added, and the whole boiled for an hour. In the course of this operation, the tin is dissolved by the cream of tartar, and the salt thus produced is acted upon by the zinc of the brass, giving rise to a soluble zinc salt, and precipitating the tin upon the remaining portion in the form of a complete coating.

Having detailed the chief characteristics of the alloys of copper with zinc, lead, and tin, as well as the various means resorted to for their preparation, it may be advantageous to describe briefly a method for analyzing them. For the sake of conciseness, it may be supposed that the alloy contains copper, zinc, nickel, tin, and lead, in order to prevent a repetition of the course to be pursued. About thirty grains of the alloy in filings, or else cut into thin slips, are introduced into a glass flask, and treated with concentrated nitric acid till the whole of the metal is decomposed. Some difficulty will attend this, if the operator overlooks the precaution of having the alloy finely divided before subjecting it to the acid. When the whole has been oxidized, the excess of acid is to be expelled by evaporation, taking care that nothing is lost by spirting. Water must be added in sufficient abundance to dissolve the nitrates of copper, zinc, nickel, and lead from the insoluble stannic acid. Heat is applied to facilitate the liquefaction, and, after it has been satisfactorily accomplished, the precipitate is thrown upon a filter, washed well with water to remove all traces of the accompanying salts, and afterwards dried in the water bath, ignited in the usual manner, and weighed. Seventy-five parts, by weight, of the stannic acid correspond to fifty-nine parts of metallic tin. The filtrate from the tin containing the nitrates of lead, zinc, nickel, and copper, is treated with sulphuric acid in excess, and evaporated till the liquid becomes well concentrated. This reagent determines a precipitate of sulphate of lead, which must be collected upon a filter, washed, dried, ignited, and weighed. In the liquid filtered from the sulphate of lead, a precipitate of sulphide of copper is thrown down by transmitting a current of sulphide of hydrogen through it. This precipitate is filtered and washed thoroughly, then dissolved in hot weak nitric acid, and boiled to expel all traces of sulphide of hydrogen; then filtered. The nitrate of copper solution is precipitated by hydrate of potassa, taking care that the liquor be previously diluted and raised nearly to the boiling point at the time of pouring in the alkali. The whole is further heated till the oxide of copper falls in the form of a dense black powder. This, which is the anhydrous protoxide, is filtered, and subjected to a prolonged washing with boiling distilled water, to separate the last traces of potassa. When thoroughly purified, it is dried, ignited, and weighed, as already directed at page 526.

The solution from the sulphide of potassium, is boiled to dispel all traces of the gas. Carbonate of soda is added, and a precipitate of carbonate of nickel and carbonate of zinc falls. This is collected, washed, and subsequently dissolved in hydrochloric acid, the solution evaporated, potassa added in excess, and, after this, hydrocyanic acid, till the precipitate which was determined is redissolved. Finally, sulphide of potassium is added to this liquor, to precipitate the zinc in the form of white sulphide. After removing the latter compound and washing it thoroughly, the filtrate and edulcorations are treated with aqua regia, and evaporated to decompose the nickelo-cyanide of potassium. Finally, by adding potassa, oxide of nickel is precipitated, and, after washing, drying, igniting, and weighing, the quantity of the metal may be estimated by deducting the weight of the filter ash, from the data that forty-one parts of oxide correspond to thirty-three of metal.

Other courses may be pursued in the analyses of the compound metals above mentioned, but that just described will answer in general all the purposes of the manufacturer.

COPPER SALTS.—The metal which has been described in the foregoing pages, is not only capable of uniting with a few metallic bodies, as shown in the construction of alloys, but also enters into combination with electro-negative elements, producing numerous compounds, a great number of which are found naturally, as stated at page 494. All these, and many more, can be synthetically prepared in the laboratory, and their distinct properties and general chemical relations minutely examined.

In the course of such experiments, it has transpired that all the compounds of copper with acids have a poisonous action, excepting the more insoluble, such as its combinations with sulphur and ferrocyanogen, the effects of which have not been properly investigated. Pereira says, that in small doses salts of copper give relief in some diseases of the nervous system, and, for this purpose, have been administered under the title of *tonics, antispasmodics*, or *alteratives*, according to the nature of the malady; but when taken in larger quantities, they occasion gastro-intestinal inflammation, and disorder the functions of the nervous system. When death ensues from these causes, it is said to be produced by *acute poisoning by copper*, the symptoms of which are a cupreous taste, violent vomiting, griping pains, cramps in the legs and thighs, headache, giddiness, convulsions, and insensibility. The usual antidote for cupreous poisons is albumen or white of egg; but gluten or milk in large quantities will serve the same end. DUMAS and others have advanced, that iron filings administered will effectually prevent poisoning by these compounds, since the acid in combination with the copper salt will form salts with the iron, and render the copper inert, by precipitating it in the metallic state. It is the Editor's opinion, however, that this is not so trustworthy as the albumen, because the amount of the metal deposited will be proportionate to the extent of surface which the iron presents. Besides this, considerable time must elapse before the reduction is complete, whereas, when albumen is employed, the combination is instantaneous, and the pernicious material is rendered inert by the formation of a bluish-white albuminate of the oxide of copper. The new compound must, however, be removed from the stomach immediately, otherwise the poison will ultimately, if in sufficient quantity, prove fatal.

Preparations of copper have been topically applied with considerable benefit to the patient. They act as caustics, irritants, and astringents.

The compounds of copper which have been prepared to any great extent are the acetate, sulphate, and carbonate of the oxide. The oxide of copper has been employed, to some extent, as a pigment, and is known as powder blue. It is, however, an unstable color, and, consequently, not much resorted to, excepting in a few cases where its use offers some facilities. It may be prepared in various ways in the laboratory. If thin plates of copper be heated to low redness in the air, their surfaces become readily tarnished; a yellow color, changing to a violet, is produced, owing to the formation of oxide of copper. Should the heat be continued and increased to redness, and then slackened, a coating of oxide of copper will be thrown off in the form of black scales. The same substance is obtained by heating nitrate of copper to redness in a crucible, nitrous acid and oxygen being evolved. Thus obtained, it is useless for the requirements of art in consequence of its color, which is black or brownish-black. In this state it is powerfully hygroscopic, attracting moisture from the air with avidity. It requires the highest temperature of a wind furnace to fuse it, and then it parts with a certain proportion of oxygen, becoming a suboxide of the metal. Hydrogen, passed over it at a red heat, effects a rapid reduction, and metal results. The same change occurs when it is heated with organic substances in close vessels. When fused with vitreous matters, such as glass, it dissolves, and communicates to the mass a blue tint resembling that produced by oxide of cobalt. It was thus that the ancients, long before cobalt was known, prepared glass of a fine azure tint. The specific gravity of the black oxide of copper is 6·4. Most of the acids usually employed as solvents dissolve it, forming more or less blue solutions, from which potassa precipitates a bluish hydrate. Ammonia, sparingly added, likewise throws down a similar compound, which dissolves in an excess of the reagent, forming a beautiful violet-colored fluid. The carbonates of the fixed alkalies occasion precipitates in solution of oxide of copper; but the most characteristic is the peculiar reddish-brown which it yields with ferrocyanide of potassium. Its chemical symbol is CuO, and its atomic or equivalent weight, 40.

When the oxide of copper is precipitated from its solutions by potassa, it forms a blue hydrate, which is the compound used as a pigment, more especially by the paper-stainers. DUMAS gives the following directions for its preparation :—Dissolve six parts of sulphate of copper, and three parts of chloride of calcium, separately, in water; then mix both liquids, and, after the sulphate of lime falls to the bottom, decant the liquid chloride of copper into a third vessel, where it must be well agitated with a cream made of one part and a half of lime. A greenish precipitate, consisting of a basic chloride of copper, falls, which is the crude compound sought. After collecting and washing thoroughly, it is ground with one-fourth part each of hydrate of lime and pearl ash, and put into bottles. It is customary to add a quarter of a part of chloride of ammonium, and half a part of sulphate of copper, when packing, to enable it to retain its blue color. If left exposed, the bluish tint would disappear, and a green be substituted. Indeed, the hue changes to this, after being applied for some time, so that it is not used to any great extent. Among the salts of copper, the carbonate and sulphate are the only ones of which a description will be given here, the reader being referred to ACETATE OF COPPER at page 39.

CARBONATE OF COPPER.—This salt, under the title of *verditer*, is employed in considerable quantities as a pigment. The composition is not, however, a true carbonate, but a mixture of this and oxide of copper. The mineral azurite, when powdered, gives a very fine blue color; but it is costly. Verditer is prepared from metallic copper and its sulphate, by the following process :—About two hundred and twenty-two pounds of copper are mixed intimately, under edge stones, with a little more than an equal weight of common salt, the powder being afterwards made into a paste with water. Two hundred and twenty-five pounds of thin sheet copper, cut into pieces an inch square, are agitated in a wooden tank or vessel with two or three pounds of strong sulphuric acid, diluted with water, to remove any coatings of oxide or other impurities which might prevent the oxidation of the metal in a subsequent operation. As soon as the acid has acted sufficiently upon the surface, it is decanted, and the fragments introduced into barrels, which are made to rotate on their axes, and thoroughly washed with water. Afterwards the bits of metal are mixed with the saline paste already mentioned, and deposited in layers in the bottom of what is called the oxidation chest. Here the metal, through the agency of the salts which absorb oxygen, becomes oxidized, in proportion to the extent of surface in contact with the air. In order, therefore, that the transformation may be as perfect as possible, the layers should not be over-thick; and they ought to be turned up once a week to present a fresh surface to the atmosphere. This is done by decapulating the contents of the chest into an empty one, and transferring the matter back into the former again. At the close of three months, the process of oxidation comes to an end. The mass is now turned over, and particles of metal which might still remain are carefully picked out. The residue is washed with the smallest possible quantity of water to separate the saline matter, and then filtered. The magma—*schlam*—remaining on the filter, is next transferred in buckets which hold about thirty pounds into a large tub, and, for every six measures introduced, twelve pounds of hydrochloric acid, of specific gravity 1·109, are added. The whole is then well commingled, and left at rest for thirty-six or forty-eight hours. The effect of this is to produce a soluble chloride of copper, from which the oxide is to be thrown down afterwards by a solution of an alkali. This is prepared, in the usual way, with caustic lime, and the proportion used is fifteen measures—specific gravity being 1·142—to every six pailfuls of the acidified precipitate already mentioned. After the usual time for standing has elapsed, the mixture is transferred quickly into the tank containing the alkali, and the whole briskly stirred till it becomes rather consistent, when it is left to repose for thirty-six to forty-eight hours. The precipitate, by this time, will have subsided. The supernatant fluid is siphoned, and the blue precipitate repeatedly washed with water, and, after the settling of the solid matter, decanted.

When all traces of alkalinity have been removed, the precipitate is thrown into filter-bags, where it is freely exposed and repeatedly moistened, and, finally, allowed to drain. After this the matter is cut into small pieces, and exposed to spontaneous desiccation in the air till it becomes thoroughly dry. The latter process may be conducted in a chamber, but the temperature should not exceed 78° Fahrenheit.

If the several operations be properly conducted, and the final exsiccation thoroughly performed, a beautiful product results; but the smallest amount of moisture, if retained, tends to injure the color, on which the value of the substance almost entirely depends.

Another variety of the same may be obtained by agitating chalk with a solution of nitrate of copper for some time; double decomposition takes place, and carbonate of copper precipitates. When it has completely subsided, the solution of nitrate of lime is decanted, and fresh additions of water made after each decantation till the residue is sufficiently purified. The color of the precipitate when dried is greenish, but the blue shade is communicated by mixing with it eight or ten per cent. of fresh-burnt lime. If this addition be made while the compound is in the pasty state, and the whole well triturated for some time, a uniform hue is produced. An inferior kind of verditer is prepared by mixing subsulphate of copper and chalk together, and washing as usual.

The composition of this body varies with the nature of the course followed in its manufacture; but a good article approaches to the annexed results of the analyses of samples of verditer:—

	At. weight.	Centesimally represented		
		Theory.	Berzelius.	Proust.
2 Eqs. of oxide of copper,	80	72·07	71·70	69·5
1 Eq. of carbonic acid,	22	19·82	19·73	25·0
1 Eq. of water,	9	8·11	8·57	5·5
	111	100·00	100·00	100·0

Verditer is employed, to a large extent, in the manufacture of paints, and as a substitute for verdigris.

SULPHATE OF COPPER.—*Roman vitriol*, *Blue vitriol*, *Blue stone.*—This is the most important of the salts of copper, and the one which is manufactured in largest quantities. Many ways are known for preparing it in the laboratory—such as exposing pure copper in thin sheets to the joint action of dilute sulphuric acid and air; treating freshly precipitated oxide of copper with diluted pure oil of vitriol, or boiling the metal with the latter compound either in the concentrated state, or diluted with an equal bulk of water. In all three a solution of sulphate of copper is obtained, from which the salt may be removed in well-defined rhomboidal crystals of a fine sapphire blue color. They are liable to effloresce when exposed to the air, owing to the escape of water of crystallization. Four parts of cold and two parts of boiling water are required for their solution; but GMELIN says that three parts of the former, and 0·5 of the latter, are sufficient to dissolve them. In crystallizing, sulphate of copper takes up five equivalents of water, of which four may be expelled at 212° Fahr., but the expulsion of the ultimate one requires a temperature of 400° Fahr. Deprived of moisture, the salt is white; in this state, on account of its hygroscopic properties, it is employed as a test for determining the presence of water in some spiritous liquids, such as alcohol, *et cetera;* when exposed to moist air, or to contact with aqueous liquids, it assumes its usual bluish color, more or less. At a very high temperature, sulphuric, together with sulphurous acid and oxygen are expelled, and oxide of copper is left. When heated in close vessels with an excess of charcoal, reduction succeeds, and metallic copper remains, whilst sulphurous and carbonic acids are evolved. Sulphate of copper is decomposed by hydrochloric acid, chloride of copper being formed, and sulphuric acid set free.

Anhydrous sulphate of copper is represented as CuO, SO_3, and the crystallized, which has a specific gravity of 2·19, as $CuO, SO_3, 5HO$.

Besides the methods mentioned in the preceding for preparing the salt, many others are followed, which, being resorted to on the large scale, will now come under consideration. Already, in the course of the treatise on the manufacture of copper from its ores, occasion has offered of showing that, by calcining the pyritous minerals in contact with air, the sulphur and copper are oxidized, so as to give rise to a sulphate of the metal; this is more especially the case if nitrate, or any other oxidizing substance, be heated with the mineral, for then nearly the whole of the sulphur will be converted into sulphuric acid, which unites itself with the oxide, and forms the substance. For extracting it, the roasted material is thrown into a tank, and a moderate amount of water added, and left to digest for some time, during which even portions that remained intact in the furnace now undergo oxidation, so as to produce sulphate of copper. The liquor after being drawn off is evaporated to the crystallizing point, and the residuary matter, left in the first tank, if not entirely exhausted of its cupreous contents, is subjected to a second roasting with a fresh quantity of ore, and exhausted with water as in the preceding instance. A very small proportion only of the sulphate of copper manufactured is obtained in this way, the chief bulk being prepared by acting upon the scales which are separated from the metal when undergoing the process of lamination; the dipping liquor of the coppersmith is also used for the same purpose. The details of the manufacture are very simple:—A stout wooden vessel lined with lead is provided, and into this a certain quantity of strong sulphuric and copper scales is introduced, both agitated and left till the solution becomes saturated with the sulphate of copper. To assist the action of the acid, steam is blown through a lead pipe passing nearly to the bottom of the tank. When the acid becomes saturated, the liquor is drawn off into other leaden vessels, arranged in a warm room, and allowed to crystallize. In the course of five or six days a crop will be obtained; the mother-lie is decanted and added to fresh liquor that is ready for crystallization. After draining, the crystals are dried and packed for sale; sometimes they are packed when merely drained of their moisture. In this operation all the scales are not dissolved—only such portions as have undergone thorough oxidation. The residuary matter remaining in the tank after the action of the acid has ceased, is washed with water, dried, and submitted to the furnace with blistered copper to be refined. The following experiments, recited in the Pharmaceutical Journal, will serve to illustrate the produce on the large scale. In one of these, five hundred and two quarters by weight of copper scales were treated with six hundred and eighty-five pounds of sulphuric acid of 1·700 density, water being added in sufficient quantity, and the produce was five hundred, two quarters, and twenty-four pounds of crystals of sulphate, together with one hundred and twenty-two gallons of mother-liquor of 1·180 specific gravity, and one hundred and sixty gallons of 1·100 density. By operating upon a portion of those liquors, it was found that the total weight of the sulphate of copper produced was equal to twelve hundred and forty pounds, and that for their production only three hundred and fifty pounds of the scales were taken up.

In another experiment, in which seven hundred weight of the scales were taken, and eight hundred pounds of strong sulphuric acid of specific gravity 1·700 added to them, together with a sufficient quantity of water, seven hundred, one quarter, and fourteen pounds weight of crystallized sulphate of copper were obtained, together with one hundred and thirty-eight gallons of mother-liquor of a specific gravity of 1·176, and one hundred and sixteen gallons of 1·080 gravity, both together holding eight hundred and twenty-five pounds of the salt in solution, so that the total quantity was sixteen hundred and fifty-one pounds of salt, leaving two hundred, three quarters, and eighteen pounds of the scales unacted upon.

The dipping liquor of the brazier is also used as a source of sulphate of copper; but the product which it affords is not of good quality, owing to brasses and other alloys being subjected to the action of the acid, and, of course, sulphates of zinc, iron, and other bases being present as impurities. Occasionally, this *pickle* is added to the cupreous liquor obtained, by acting upon the scales with vitriol, and the whole crystallized; the product, although serviceable in some cases, cannot, however, be used in place of pure salt.

Considerable quantities of sulphate of copper are employed in the preparation of other compounds, such as verditer, acetate of copper, *Scheele's green, et cetera.* It has likewise been found serviceable in agriculture for the purpose of steeping the seeds, in order, as is said, to prevent thereby the ravages of insects, the smut and other analogous blights in the crop; but the inferior kinds are taken for this purpose. It has also been employed to saturate wood or timber as a preventive against the dry rot. In medicine it is frequently prescribed, and it becomes a base in several of the green and blue colors applied in calico-printing.

The method of analysis which is followed in determining the value of the salts of copper, is similar to that described for the estimation of copper in ores or alloys of the metal.

DISINFECTANTS.—*Desinfectants*, French; *Faülnisswidrige substanzen*, German.—This class of substances, although a few of them have been long used, has only lately been distinctly recognised. Properly speaking, they are such as remove the *causes* of infection, but, as the French signification has been adopted in England, the removal of any injurious taint is also understood. This so enlarges the meaning that it must embrace,—Firstly, Antiseptics, or agents which prevent animal and vegetal matter being decomposed in such a way as to emit deleterious gases or fluids; secondly, Deodorizers, such as interrupt decomposition when it has begun, or destroy hurtful emanations when formed.

The ancients seem to have attained the knowledge of the first variety at a very early period, as the process of embalming shows. The body, after the removal of the viscera, was washed with palm oil and aromatic substances, and was then filled up with powdered myrrh, cassia, and other perfumes; after this it was buried in *natron*—soda—for seventy days, and, finally, was protected from atmospheric action by being enveloped in gummed cloth. Or, for a cheaper process, the intestines were filled with what HERODOTUS termed *cedar oil*—turpentine—and the body salted; the former having consumed the flesh, leaving only the skin and bones, was then removed. At other times, it is stated, the corse was merely treated with a cleansing wash, and then *steeped* in soda. The body may, perhaps, have been *bathed* in caustic soda, but it could not possibly have been immersed for a long time in such a powerfully alkaline liquor; probably the carbonate and sulphate and common salt were employed. Others, and the greater part of the mummies, were treated with asphalt only, becoming one black mass, where the features are destroyed.

The burning of bodies is another mode of removing infection, and this was resorted to when it was desirable to preserve the remains in a smaller space than was consistent with embalming. In this case the ashes took up but little room, and were generally deposited in urns; hence the little niches like pigeon-holes, forming the *columbaria* of the Romans, for the reception of such vessels.

As substances which are deprived of their water do not decompose, drying was also adopted at an early period, both amongst the Egyptians and in other countries, as a means of disinfection, and there can be little doubt that this formed a part of every process of embalming. The preservation of bodies is due to the dryness of the receptacles, as well as to the art of the embalmer.

Washing with pure water to remove all putrescent or putrescible matters, has always been, and must continue to be, the most important disinfectant, whenever it can be applied. Hence came the purification of early times. This was undertaken whenever anything noisome, especially a dead body, had been touched. The Mosaic command on such occasions is to wash the clothes of the infected person, and set him apart as unclean until the morning, or longer, according to circumstances; thus ablution is considered insufficient—time also is needed. This is not a mere symbolical or moral impurity demanding time, even after the cleansing, without a physical cause; it is also a kind of quarantine, established in private, is perhaps useful, and at least is incapable of doing injury.

The disinfection of houses was the work of the Jewish priests. It frequently happens in this climate that the walls of houses which become damp, collect a large amount of organic matter which decomposes, and renders the place unwholesome. Among the Jews a somewhat more alarming form of the evil took place, called *leprosy.* This was probably caused by the large amount of organic matter employed in the plastering of the building. In this case the infected part was removed, the walls scraped, and the dust from them thrown into a receptacle for filth without the city. If this did not effect the object, the house was pulled down and the materials removed.

It has been suggested, with some plausibility, that the leprosy on walls and garments alluded to in the book of Leviticus, was a fungous growth which infected these bodies, and which was found capable of being communicated to man and other animals, so as to produce in them contagious disorders.

It has generally been found that the soil is a very valuable disinfectant, decomposing animal matter with great rapidity, and sending out gases which are, on the whole, innocuous, unless sufficient space has not been allowed for the remains.

Efficacious as the soil is for the disinfection of bodies buried in it, it has been found in large towns that the amount of soil covering the dead has been insufficient; most nations, therefore, have interred their dead in the suburbs and less populous localities. This was apparently the result of a long experience, as it is found that the Athenians at first imitated the Egyptians, and kept their dead in the house; the corses, however, not being embalmed as in Egypt, were found not to be fit objects for the presence or immediate neighborhood of the living, so that the custom was relinquished even in very early times. The inhabitants of Sparta and Megara buried in the town, but this was done for a moral purpose,—to remove that fear of the dead and of death, which was considered by the Spartan as so debasing.

If there be any truth, says Dr. DAUBENY, in the opinion entertained as to the noxious properties of the gases exhaled during the process of animal putrefaction; if the effluvia which emanate from dead bodies are capable of becoming the vehicles of any infectious principle, whether proceeding from fungi or otherwise, then the practice of burying within towns, or indeed anywhere within a church, ought altogether to be abandoned.

Should the wholesome fear engendered by the awful malady with which this country was visited in 1832, in 1849, and in 1854, prove the means of putting a stop at once and for ever to a procedure which is not only pernicious, but which, if the English people were not habituated to it by long usage, would be regarded here, as in other lands, disgusting and repulsive; should it enforce a more thorough system of drainage, and a more complete removal of unwholesome impurities; should it induce a greater attention to the comforts of the poor, and to the healthy condition of their dwellings; then, indeed, the designs of Providence in inflicting such a scourge will no longer be involved in mystery, since it will be seen that permanent good, both moral and physical, has resulted from a local and temporary evil, inasmuch as the exertions made to ward off the invasion of a foreign pestilence, have not only succeeded in disarming at the same time the malignity of those domestic foes which are always hovering about in the form of typhus and scarlatina; but have likewise promoted, in an eminent degree, the general well-being of society, by affording to the poorer classes of the community, the means of breathing in their dwellings a purer and healthier atmosphere, and of cultivating amongst themselves habits of greater cleanliness and propriety.

A process of purification after the burial of a person was, among the ancients, nearly universal: sometimes it resolved itself into a mere religious custom, but this had evidently risen out of a distinct act of cleansing. The Romans called it *suffitio*, a fumigation; the inmates of the house from which the body was taken were purified by being sprinkled with water, and by stepping over a fire; evidently typical of the influence of fire and water for disinfecting purposes. Certain days were set apart for the ceremonial cleansing of the family, and the house was swept out by an officer appointed for the purpose.

Embalming has sometimes been resorted to in Europe from the very earliest times, and with great success. The remains of the French kings disinterred at St. Denis by the revolutionists, preserved their countenances, it is said, perfectly when first uncovered; but immediately disintegrated when exposed to the air. Abundant instances are found in history of similar preservation, although the particulars of the processes adopted in the middle ages are less known even than the Egyptian methods, while, at the same time, they appear to have been more successful. Sometimes the preservation is effected by the mere action of a constant current of air. This may be readily believed of a warm climate; but the same result occurs at Bonn, in the vault of a chapel, where the bodies of the buried monks are dried up and shrivelled, but not decomposed. No means whatever, it is said, are used to obtain this result, further than placing an open coffin containing the body, in a dry repository where the wind is continually blowing. Such examples require some explanation, and this subject, like many others, has its obscurities.

There was a time in Europe, and especially in Hungary, when the preservation of bodies caused great alarm, as it was supposed that in such cases life was still remaining in a peculiar condition. Examples of this kind were called *vampires*, and were supposed to rise in the night and suck the blood of the living. They were compelled to decompose, however, by being struck through with a stake, and sometimes also by having their heads cut off; further, if great care was required, they might also be burnt. The remarkable history of vampirism in Hungary is no doubt connected either with the great ignorance of the signs of decease, and haste in consigning to the grave, or with the peculiar circumstances or the place of burial, whereby the bodies have been preserved. Probably both causes combined to produce the strange results.

Out of the original idea of purification and disinfection many ceremonies have arisen; such, in all probability, are *lustrations*, and all those in which incense is used; sometimes, however, the pith of the matter was lost, and the simple form only remained. When ULYSSES burnt sulphur to remove the infection emanating from the dead bodies of the suitors, he retained the original rite, which had not lost its meaning in mere antics. When the Roman shepherds burnt sulphur and herbs once a year, sacrificing to PALES, and adorning their folds with wreaths, part of the original process of disinfection was retained, but it was rapidly degenerating into mummery. The perfumed oils put on the bodies of the dead, were more for the concealment of the effluvia than for any powerful disinfectant quality which they possessed, although by no means entirely wanting in that respect.

Closely connected with the decomposition of animal matter is fermentation; and bodies which prevent the one, frequently interrupt the other. In the manufacture of wine, the intestine motion may be checked by the use of some oils, such as turpentine, as well as of acids, especially the sulphurous. When fermentation is completed, oxidation and the formation of acetic acid may commence, or complete decay set in. To prevent this, the ancients employed *conditurœ* and *medicamina* of various kinds—sea-water, turpentine or resins, caustic lime—either from common limestone, marble, or shells—gypsum, aromatic herbs and spices, gums, and *must* inspissated. The vessels were also sometimes lined with pitch, and occasionally powdered pitch was thrown into the fermenting juices. Besides these were used almonds, raisins steeped in must, parched salt, goats' milk, cedar cones, gall-nuts, and blazing pine-torches, or red-hot irons quenched in the liquid. Salts of lead were also in request, either to alter the taste or to prevent decomposition, and remove impure matter and clarify the wine. In some places aloes were employed, producing a slight bitter, like that of the well-hopped Burton ale of the present day; in others, the flavor—as in the Scotch and Irish whisky—was given by smoke.

Although the ancients do not appear to have laid down very correct theories as to the decomposition of organic matter generally, they proved their knowledge of the necessity of preventing the emanations of marshes, by drying them up; of shutting out certain winds, by completely stopping all the crevices on the exposed side of their houses; whilst they also used aromatic herbs, and kindled fires in the streets in time of plague.

CAUSES OF INFECTION.—Infection arises from decomposing matter, which, coming in contact with that which is healthy or sound, induces a continuation of the decay. It is in this wide sense that the word is used when *disinfection* is spoken of. Matter may be thrown into this state in various ways and situations. Vegetal and animal substances decay spontaneously, even if left to themselves, without the interference of any body in a state of eremacausis. No infection is known without the presence of such putrefying agent. The origin and history of all plagues and infectious diseases point to this satisfactorily. No chemical reagents, properly so called, have been ascertained to give rise to contagion. Gases are known which destroy health, and by producing decomposition may cause such decay to proceed in the system that the exhalations may engender infection; but even in this case it is produced by the organic substances, though the distinct and direct injury is effected by the chemical agency. What, then, are the sources whence disease may arise? When carbonic acid is eliminated from the soil,—as is so frequently the case in Italy; on some of the mountains of Thibet, as HUC mentions in his travels; in several valleys in the East, and in various caverns in Europe,—disease is produced by a rapid destruction, or by a gradual lowering of the vital force, according to the abundance of the gas. Disinfection in such cases can only arise by the removal of the cause, which, however, does not seem in the power of man to accomplish. When an earthquake disrupts a country, and sulphide of hydrogen is poured out, a similar result arises, not to be affected by human agency. Another example of uncontrollable chemical action is found in the decomposition of vegetal matter carried by rivers—as the Quorra—into the sea, rendering the atmosphere of the coast, and even a great portion of that of the neighboring ocean, unfit for healthy respiration. But when it is possible to prevent the entrance of the sea into the mouth of the river, and so to avoid its mixture with the fresh water contiguous to the land, the air becomes more wholesome. Probably the fresh water animals and plants are destroyed by the brine, and *vice versâ*, and thus a constant interruption of life takes place, with a continued struggle to proceed; the decayed matter in such a case being very great, and the mephitic vapors rising in unusual abundance. The coast of Italy on the Maremma supplies instances of this kind.

Again, when a country is badly drained, and there is no outlet for the products of the decomposition of plants but the air, it often happens that disease spreads rapidly. If the land be properly drained, these emanations passing through the soil become disinfected, and a comparatively healthy atmosphere results. Marshes in all ages have been unwholesome; but they are so in proportion to the temperature and the state of vegetation. A damp climate and a moist soil, such as those of Holland, do not produce disease in an equal degree with a similar condition in the tropics, where decay is more accelerated. Still, even in Holland, those who live in the immediate neighborhood of that part of the country which is adjacent on one side to the sea, and on the other to fields below its level, are far inferior in appearance to those who live where the land is elevated only a foot above the ocean's surface.

Diseases sometimes seem to arise from a greater expanse of sea than above alluded to, at least when connected with one or more great rivers. A reddish vapor was seen by the inhabitants of the surrounding country, to their great alarm, to arise out of the Yellow Sea; after floating about, it dispersed itself over the land, and produced—or, at least, was followed by—that most dreadful outbreak of cholera, which afterwards gradually passed over all Asia, ultimately coming to Europe. Means of cure are not readily found for such cases, but recourse must be had to energetic disinfectants.

Ponds, and such collections of water as are too shallow to prevent rapid decomposition, and which allow the sun's rays to enter so as to encourage the growth of plants at the bottom, become fertile sources of disease. They can only be disinfected entirely by destruction of the vegetation, generally accomplished by complete drainage.

Masses of matter in a state of decomposition around a dwelling may easily become centres of contagion; and the best method of dealing with these is to remove them immediately, but, if in a dangerous condition, to disinfect them previously, as the removal abundantly spreads the noxious vapors and gases.

A still atmosphere favors the spread of infection, as a whole district or country may become like a closed vessel, rapidly filling up with impure matters, and pestilence being consequently generated. Hurricanes, it is well known, have a powerful tendency to stop the progress of disease. Before the plague of London, an unusual calm occurred.

Sudden changes in temperature are likewise injurious, affecting the healthy condition of animals and vegetals, causing decomposition, and occasioning infection. The peculiar condition of the air called *blight* is a state of this kind, but is imperfectly understood. Great natural phenomena in any way interfering with organic life, may accelerate various maladies. Rain has sometimes been so continuous as to cause a whole district to become corrupted; destroying vegetation, and not only starving, but infecting man with offensive emanations. So also great swarms of insects,—locusts and caterpillars, for example; better known in history than by the experience of the present day,—droughts and pestilential heats—are similarly destructive of animal and vegetal life.

These causes of infection have been recounted, that a distinct view of the opposite, or disinfection, may be taken. Vapors arise in all these cases mentioned, and pervade the atmosphere. That organic matter has been found in the air, has been sufficiently proved by EHRENBERG, who ascertained the presence of animalcules; by VOGEL and Dr. SOUTHWOOD SMITH, and more recently by Dr. ANGUS SMITH, who obtained it in the moisture condensed from the breath in crowded rooms. A state of the atmosphere in which organic matter does not exist can scarcely be imagined; even when it comes from healthy bodies it is found to be injurious if allowed to collect; but when emanating from unhealthy constitutions, it must communicate disease much more readily. Its first action is on the nasal organ, where nature generally gives notice of contiguous evil; but when persons are accustomed to living in impure air, habit causes them to be insensible to its effects. It must next enter the lungs, where the blood absorbs it; distemper is thereby communicated to the most vital parts in a direct manner.

Infection coming by anything solid, or even liquid, is not readily imagined; it is true, solids may so cover up the pores of the skin as to eventually produce disease, and fluids may be so spread over the body as to be imbibed, and occasion a similar effect; but vapors enter at once into the lungs and blood, and it is, therefore, against these that the use of disinfectants must be principally directed. Two classes of vapors have to be encountered,—the inorganic and the organic. The former cause disease by lowering the tone of health in a way never yet satisfactorily explained; they are chiefly the result of manufacturing operations. It is certainly advisable that this source of disease should be avoided with the utmost possible care, so as not to injure the manufacturer. Every art should be carried on so as to do the greatest amount of good and the least injury: any work not conducted on scientific principles, when it is possible to arrive at them, should certainly be compelled, after due evidence is obtained from scientific and competent men, to alter its system. It is scarcely possible to lay down rules in such a case; the method must vary with the place. It would be absurd, for example, to subject a factory in the country to the same conditions as one in the midst of a populous town.

ANTISEPTICS.—Sir JOHN PRINGLE gave a table of the power of antiseptic bodies, and showed that they were very numerous, and that salts of every kind, whether acid, alkaline, or neutral, fixed or volatile, as well as all astringent and gummy resinous matters, were antiseptic. Dr. MACBRIDE also, in the middle of last century, wrote a careful treatise on that class of bodies, giving the results of many experiments as to their value, showing especially the great power that acids possess. He first tried sulphuric, hydrochloric, tartaric, and acetic acids; finding tartaric acid to act with the least energy, acetic and citric standing next in the scale, the sulphuric and hydrochloric being most valuable. He then employed ammonia, and its carbonate and acetate, and carbonate of potassa, and ascertained that each of them had preserved a piece of mutton put into it—not, however, so as to be eatable—quite sweet for three weeks. The effects of asafœtida, aloes, Virginian snakeroot, pepper, ginger, saffron, contrayerva root, sage, valerian root, rhubarb, mint, angelica, senna, and common wormwood, were found to be inferior to those of camphor, of which Sir **JOHN PRINGLE** said that it had three hundred times greater antiseptic power than sea salt. Horse-radish, mustard, carrots, turnips, garlic, onions, celery, cabbage, and colewort, were likewise proved by Dr. **MACBRIDE** to retard putrefaction. Lime was discovered to be strongly anti-putrescent so long as its causticity was preserved, but to have no efficacy whatever to arrest putridity when it had been converted into carbonate. Alcohol had no power in correcting decay, although capable of preventing its commencement.

Astringents, according to Dr. **PETIT**, act as antiseptics, by causing the close union of the particles of matter, thereby impeding decomposition or separation.

Sir **JOHN PRINGLE** and Dr. **MACBRIDE** ascertained that the fresh vinous fermentation was capable of removing putrefaction; a soft, decayed piece of mutton, after being immersed in fermenting molasses for one hour, was made sweet and firm. Meat was disinfected by fermented liquors—as ale or wine—which contained alcohol, while sugar and water had no effect. Dr. **MACBRIDE** ascribes the antiseptic properties of vegetal food to the large supply of air which they give. This, however, is using the word in a wrong sense; there can be no doubt the power of removing scorbutic disease is alluded to; including also, to a great extent, plagues and other epidemics, now much less known than formerly.

The second edition of Dr. **MACBRIDE**'s book was published in 1777, and he therein refers to the great antiseptic power of acids being well known. Dr. **CARMICHAEL SMYTH** afterwards, in the hospital at Winchester, had great success in disinfection, and in the fleet at Sheerness was mainly the cause of the removal of a most deadly pestilence by employing nitre—nitrate of soda—and sulphuric acid, fumigating the rooms whilst the patients were in them, and also taking care to expose their clothes to the nitrous vapors evolved. The great value of this method is unquestionable, but its numerous disadvantages have raised objections sufficient to discontinue its use. The fumes caused the patients to cough violently, and long exposure to them would certainly have been injurious in the extreme. Still, experience has shown it to be a powerful disinfectant, and it was unwise not to provide a substitute. **GUYTON MORVEAU** considers that Dr. C. **SMYTH** took the discovery from him, but he chiefly recommends hydrochloric acid, and his first experiment was made in 1773, long after **MACBRIDE**'s book had been published. **MORVEAU** had evidently read **MACBRIDE**'s work, as he quotes his use of lime, and finds it unsatisfactory. He gives, however, valuable information on the nature of disinfectants, and a most luminous series of experiments. Some, also, of his countrymen had been in the field before any of those already mentioned, but the subject was now beginning to take a definite form. Mr. **CROOKSHANK** had introduced chlorine into hospitals in England, and **MORVEAU** considers this as the best of all disinfectants, having given up his own method—hydrochloric acid gas—in order to adopt it. It was in regular use in Woolwich.

The last-mentioned authority says that the burning of fires is not essentially useful during plagues, as they occasion an increase of temperature, and, consequently, of the evil. At Marseilles, fires were burned for three days, so that the air was covered with black smoke, which augmented the heat, and added fuel to the disease. This shows how very still the air must have been at the time, as in large English towns the atmosphere brightens at once as soon as the chimneys cease to emit smoke, and Sunday is always clear. He believes air to be of little value as a disinfecter, decomposing very slowly morbific substances exposed to it, and considers that lime, in a caustic state, prevents putrefaction, by absorbing the moisture of matter submitted to its action; but, when wet, decomposing them and disengaging ammonia. Vinegar he pronounces one of the best disinfectants, especially from its ready evaporation. Carbon he found to have great power in condensing vapors, and purifying water filtered through it, although it had no power of depurating the air at any distance. Sulphur was not discerned to have much disinfecting force, but when ignited, eliminating fumes of sulphurous acid, he agreed with others that it had very valuable purifying properties. Nitrous acid, introduced by Dr C. **SMYTH**, he regards as one of the best and most precious agents for disinfection; he recommends the use of the nitric with the sulphuric acid, cold rather than warm, although in the former case the fumes are not so readily eliminated. No doubt there are many cases in which it may yet be used, such as cleansing a ship in the absence of its crew, and similar instances.

VENTILATION.—It was only during last century that decided attempts were made to purify the atmosphere of ships and hospitals, and one naturally wonders how mankind dragged themselves along in such situations without these priceless aids. The immense losses of valuable lives which occurred, compelled the undertaking of some project; not that the want was before unknown; even **CELSUS** recommended thorough drafts, and **AGRICOLA** drew up foul air from his mines. Sir **CHRISTOPHER WREN** made, perhaps, the earliest attempts to ventilate the House of Commons, which has always been the headquarters of such schemes. Although his plan had excellent points in it, he did not succeed in entirely preventing back currents of air. An application was made to Dr. **DESAGULIERS**, the son of a French Protestant refugee, to ventilate the House in 1723. He used a blowing wheel, the principle of which is the same as that of the fan. His attempts to get it introduced into the Admiralty, the ships of which so much needed it, were at the same time amusing and provoking. Mr. **SUTTON**, a brewer, and a man of great energy, proposed to draw out the foul air by fire; that is, by causing a draught by means of a heated column of air, now so much employed; but the dislike of Sir **JACOB ACKWORTH** to innovations prevented complete success. Dr. **HALES**, after this, proposed a perflating apparatus, which should rapidly change the atmosphere. It was a box with a movable midriff, which, like bellows, blew pure air into the lower part of the ship. Admiral **VERNON**, in spite of these inventions, was sent to Carthagena with wind-sails only, and terrible losses by disease were the consequence. Dr. **ARNOTT** says that the fatal defect of Dr. **HALES**' machine was in the construction of the valves, which were too heavy, and he invented one with a curtain valve in place of the wooden or metallic ones of the latter. This consists of a curtain of oiled silk, or cloth of fine texture, hanging against a grating or network of wire fixed across the opening, however wide. If the pump be very large, the curtain has to be formed of several pieces, which overlap each other at their lower edges; there is no limit to its size, and it has no sensible weight. Twenty cubic feet of air, weighing about one pound and a half, are as easily passed through this as the same weight of wood floating in a pond can be moved along by a stick. Proof, according to the inventor, has been sufficiently made; he says that the moderate labor of one man will supply breathing air for a thousand or more people.

Sir **HUMPHREY DAVY** heated the air between hot bricks, and removed the foul by means of an iron pipe. His plan, had it been carried out with vigor, would evidently have been successful.

Dr. **REID**, so well known in ventilation, proposes to use various materials for mixing with the air, fumigating and ventilating at the same time, and acting on the body and mind by medicinal agents given in the breath. His list comprises the following:—

Dry air.
Dry and hot air.
Dry and cold air.
Hot or cold air in rapid motion.
Moist air, warm or cold.
Steamed air, or steam baths.
Highly oxidizing air by an infusion of oxygen.
Deoxidizing air by dilution with nitrogen.
Deoxidizing, by adding minute portions of agents known to have such properties.
Nitrous oxide—laughing gas.
Nitrous and nitric acids.
Chlorinated air.
Sulphurous fumes.
Carbonic acid.
Ammoniacal gas.
Hydrocyanic acid vapor.
Acetic acid.
Arsenical or mercurial fumes.
Alcoholic or ethereal vapors.
Benzoic or camphoric fumes.
Air impregnated with the odor of lavender, orange, or cinnamon.
Creosotic vapor.
Sulphide of ammonium.

The real effects of these have not been shown, and it is very uncertain which of them will do good, or how many may be productive of serious evils.

QUARANTINE.—The great expedient for disinfection in all countries has been *quarantine.* Supported, at first from sanitary causes, and afterwards for political purposes, by various governments, it has itself become a great source of contagion, as well as of many minor inconveniences. From a suspicion that all disease must have had some distant origin, not seeing any source near at hand, men have imagined, that by shutting out all persons and property they were safe, whilst few looked for the cause of sickness amongst themselves. If ancient authors be referred to, it is found that they knew the injurious effects of filth; but the information was not diffused, and probably no one individual saw the whole question quite clearly.

To shut up the population in a town, forbidding the entrance of any one, is a most injurious plan; whilst leaving the crowded area, and encamping at a distance in a comparatively pure atmosphere, has always been found to produce complete disinfection. In the present day, it has been seen that cholera has compelled many of the inhabitants of large towns to adopt this method, and with the best results, although it has been necessary for them to encamp in tents in very damp weather. This shows that the disease really arises from materials in and around dwellings, which must be disinfected and removed, or rather taken away first, and the place of deposit afterwards disinfected. The last chapter in the history of cleanliness has been by no means arrived at; the subject seems to grow as civilization advances, and as man becomes more intellectual and refined in his organization, he appears to suffer most from its neglect. Although it is probable that quarantine is entirely unnecessary in most communities, it is still possible, notwithstanding the views of those who oppose it, that contagion may be introduced by one person or thing, which will modify every disease it meets, bringing them to its own type, and so making use of all the centres of disease within its reach for its own purposes. It is possible, then, that quarantine may be advantageously employed in some cases; but to coop up persons from an infected country in a narrow boat, or to put them in unwholesome dwellings, as is generally the case at quarantine stations, is only to sow in them the seeds of disorders which may break out after they are set at liberty. As at present conducted, it is a disgrace to every country which adopts it, and it is to be hoped that the laws on this subject will soon be modified.

NATURAL DISINFECTANTS.—The atmosphere is a great disinfecter, partly by its removal of contaminating matter, and partly by its power of oxidation. Stagnant air is incapable of disinfecting the usual vitiation of towns, or even of the country, with sufficient rapidity, much less can it purify a room subjected to any source of foulness; consequently, it does not cause rapid oxidation. But when a current comes, and mixes the vapors from the earth with the enormous expanse of air above, or carries them away to the ocean, there is then given to them so much space for purification, that before the same air can again come into contact with human beings, it is perfectly innocuous. Under this head comes ventilation, already alluded to, and details of which, as being an entirely mechanical method of disinfection, would be out of place here. The results of ventilation in crowded rooms are marvellous. For example, in the Dublin Lying-in Hospital, for four years previous to 1786, one thousand six hundred and thirty-two people died, while, in the same time, the deaths are now only one hundred and sixty-five. In ventilating, it is advisable to admit only the purest air: it is well known that vapors arising from low, especially from damp grounds, are prejudicial to health. These sometimes rise very high, but frequently they may be seen to cover the ground to the height of a few feet only; it is in general safer to take air into the building from an elevation of ten or fifteen feet, than from the surface of the earth alone, and especially not to contaminate it by drawing it through a damp cellar, or from the back of the house, where it is never so pure as at the front.

Water is the next great disinfectant employed by nature. It is true that moist bodies decay more rapidly than others, and that a certain amount of humidity is essential to eremacausis; water is, therefore, both a great corrupter and a great purifier, according to the circumstances of the case. It is a disinfecting agent by the simple act of washing; this is its mechanical, and probably its most important effect. In this way each shower of rain becomes a natural disinfectant to the atmosphere, bringing down with it the floating organic substances and diffused gases. Every river is a great remover of substances capable of decomposition, because, however pure it may be, if water be allowed to remain stagnant for a short time, it will be found that there is matter enough in it to cause putrefaction. The ocean also disperses the decaying material abroad, removes it from the land, mixes it with purer water, dashes it about in the air, and thus produces oxidation and purification. Water is the only fluid that will communicate to the skin the feeling of freshness, an accompaniment of cleanliness, and so exceedingly liked by every person that it must be pronounced a most natural and wholesome condition; indeed, so much is freshness generally esteemed, that it stands in the language as a very type of vigor and beauty. In all cases where water will remove the evil, it ought to be used as the most efficient and agreeable.

Soil is another great disinfectant, and, in conjunction with air and water, is the most efficient of all. The water carries into the soil the impurities it meets with; the air penetrates the water, and is also powerfully retained by the soil, as it is by all porous bodies, and by this means the organic and putrid substances are brought into contact with the oxygen, and oxidation is made forcibly to take place. Hence a field manured with the most fetid compounds gives off no smell after the lapse of a few days, or even hours, and the water drained from it is even pleasant to drink, provided the drains be sufficiently deep. Were it not for this agency, men and animals would soon render the country uninhabitable. From this cause, too, the soil of a city is freed from impurities, and instead of albuminous bodies containing nitrogen being found in it, the nitrogen is oxidized, and nitrates are formed, except in instances where the abundance of animal matter is more than can be acted on by the soil.

The greatest remedial measures that can be adopted for the general disinfection of a country, are, therefore, air, water, and land drainage, all, to some extent, under the power of man; the latter almost entirely so.

Besides these, there is another natural agent capable of modification, namely, *light*. Although it is given in abundance, yet the mode in which many towns are built shuts it out to such an extent that many persons suffer severely. Fortunately, the abolition of the window-tax has taken away all cause of complaint in that direction for future buildings, and now the chief objection is against narrow streets in some parts of large towns, not easily altered. It is a fact, proved beyond denial, that light gives life, but in what manner no one can say. Without it, plants lose their color, and man never attains vigor; but the explanation is still in obscurity, which science has not been fortunate enough to remove. To one aspect of this peculiar power, Baron REICHENBACH has given the name of *Od*, which Dr. GREGORY has translated into *odyl;* and scientific men have rather stood aloof, not caring to know, but, at the same time, perfectly convinced that there must be some reality in it. Science is undoubtedly indebted to the Baron for his observations, although some of his theories may be afterwards modified very considerably.

To allow the admission of light, air, and water into all apartments in due measure, becomes, as may be concluded from the foregoing, an important element in disinfection; and what is true of rooms, is applicable to clothing and other materials; for these cannot be kept clean unless acted upon by air and water, nor perfectly wholesome unless exposed to light. In a barrack at St. Petersburg, there was only one case of disease on the side laid open to a strong light, to three on the dark side.

There are two agencies, partly natural and partly artificial, which check decomposition, and in suitable conditions entirely arrest it; these are heat and cold; it is necessary to treat them as distinct, because they present themselves as such. The former prevents decay by drying, as well as by changing the chemical state of substances. Albumen coagulates at 140° Fahr., and after this does not so readily decompose. At this temperature most organic bodies are, to some extent, cooked, and their condition greatly altered. Dr. HENRY found that at 200° Fahr. pestilential matter was removed, showing that, with this amount of heat, a change occurs in organized bodies, making them less capable of entering into eremacausis. The violent sausage poison of Germany is entirely destroyed by heat.

Cold, of all antiseptics and disinfectants, is the most powerful, but it can seldom be had recourse to, because it is not much under control; and when it can be commanded, it cannot be applied to living beings, and it may be added, that when it is removed, the former condition again sets in. The ice-buried animals in the North are a well-known example. Anything liable to decompose, or evolve mephitic vapors, should never be kept warm. Putrid matter exposed to the warm sun and air, if moisture be allowed it, rapidly disintegrates; if frozen, it is instantly rendered inoffensive. So frosts prevent decay and disease, and show their connection. Under the influence of intense cold, chemical action ceases; particles of flesh remain firmly united, as if they were in reality what they resemble in hardness—a piece of rock.

ARTIFICIAL DISINFECTANTS.—Acids are preservatives of organic matter, as experiments have shown; pyroligneous acid very much so. This probably arises from its containing a little creosote, which is a powerful antiseptic, coagulating albumen like heat, and preventing decomposition. For the same reason smoke, which holds a little creosote, has long been employed as a preserver of fish and flesh; a very small amount is needed, a large quantity could not be used with safety. Acetic acid has been used for an indefinite period for fumigation; creosote, in the form of smoke, has been long known, and the vapor from wood especially, which is pyroligneous acid; fir-wood, the gases from which contain turpentine, is in great favor as a fumigator.

Peat-bogs, which generally have an acid reaction, preserve substances for many years. Bodies containing nitrogen undergo the most unwholesome decomposition, and give out ammonia; acids prevent the evolution of this gas, by uniting with it, and forming a neutral salt, and so decay is interrupted. Thus, vinegar is employed for pickling; alkalies, on the contrary, favor decay. The experiments of **MACBRIDE** show that they prevent putrefaction; but this happens only after they are added in considerable quantity; even then they accelerate decomposition of a different chemical character.

Tannic acid and other astringent substances are disinfectants. Tan-yards generally contain a great deal of filthy matter, but the workmen are always accounted healthy Whether there be any principle involved in this worth taking up and carrying out, is an interesting question.

It is commonly believed, and has been stated in many chemical works, that charcoal is antiseptic. The very reverse of this is the fact, as shown by the condition of the bodies of animals which have been long buried in it, which are usually in an advanced stage of decay. This opinion has, doubtless, arisen from the fact, that the ordinary evidences of decomposition—disagreeable effluvia—are absent when bodies are disintegrated in contact with charcoal, the gases being absorbed as fast as they are formed.

The following table exhibits the amount of the most important gases imbibed by a single volume of box-wood charcoal, as determined by the experiments of **DE SAUSSURE**:—

	Volumes.
Ammonia,	90·00
Hydrochloric acid,	85·00
Sulphurous acid,	65·00
Sulphide of hydrogen,	55·00
Nitrous oxide,	40·00
Carbonic acid,	35·00
Carbide of hydrogen—$C_2 H_2$,	35·00
Carbonic oxide,	9·42
Oxygen,	9·25
Nitrogen,	7·50
Bihydride of carbon—$C H_2$,	5·00
Hydrogen,	1·75

Dr. **STENHOUSE** has recently performed a series of experiments, tending to show the relative value of wood, peat, and animal charcoal. Half a gramme of each kind absorbed the undermentioned number of centimetres of different gases:—

Kind of charcoal.	Ammonia.	Hydrochloric acid.	Sulphide of hydrogen.	Carbonic acid.	Oxygen.	Sulphurous acid.
Wood, ..	98·5	45·0	30·0	14·0	0·8	32·5
Peat, ...	96·0	60·0	28·5	10·0	0·6	27·5
Animal,..	43·5	—	9·0	5·0	0·5	17·5

It thus appears that wood-charcoal possesses the highest absorbent power for ammonia, sulphide of hydrogen, and sulphurous acid; while animal charcoal is decidedly inferior to those of wood and peat as an *absorber* of gases.

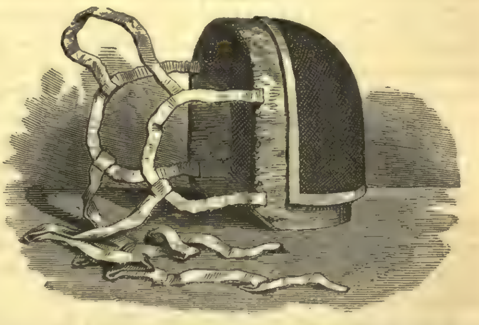
The deodorizing properties of charcoal arise, in some measure, from its great absorbent power, and this is dependent on its extreme porosity. Mr. **TURNBULL** of Glasgow placed the carcasses of two dogs in a wooden box, on a layer of charcoal powder a few inches in depth, and covered them over with a quantity of the same material. Although the box was quite open, no effluvium was ever perceptible, but on examining the bodies at the end of six months they were found to be very much decayed. The charcoal which surrounded them was found to contain appreciable quantities of nitric and sulphuric acids and phosphate of lime, a little ammonia, and scarcely a trace of sulphide of hydrogen.

There is good reason for believing that charcoal is not only an energetic absorber, but also that it is a powerful oxidizer of gases, and that its beneficial operation in many instances arises as much from this as from its imbibing qualities. This oxidizing disposition renders it improper that it should be mixed with manure, since it would destroy some of those products of decomposition upon which the fertilizing power is dependent, and so greatly reduce the actual value of the compost.

Although the absorbent powers of charcoal are so great, some have doubted whether it really is a disinfectant. This opinion has probably arisen from imperfect views of its *modus operandi.* Since it not only imbibes and destroys all offensive emanations, and oxidizes many of the products of decomposition, there is scarcely a reasonable ground of doubt remaining that it does really possess the property of *a true disinfectant, acting by destroying those lethal organic compounds upon which infection depends.*

Dr. **STENHOUSE** has recently availed himself of the absorbent property of charcoal in the construction of a respirator, represented in Fig. 347, which promises to become a sanitary instrument of great value. It consists essentially of a hollow case made of fine flexible wire-gauze. Internally, it is about half an inch wide, and of sufficient length and breadth, when folded over the lower part of the face, to cover closely either the mouth alone, or, if required, the lower part of the nose also. The hollow space is filled with coarsely powdered charcoal, and the whole, like the metallic respirator, is fitted to the face, and fastened over the head by attachments of ribbon. All the air that enters the lungs must pass through this charcoal sieve, and is thus deprived of the noxious vapors or gases it may contain. After some time the charcoal powder becomes saturated, or too old to act with efficiency, but an ounce of powdered wood charcoal renews it, and the instrument is itself again. Dr. **STENHOUSE** has also shown that platinized charcoal has a still greater power of oxidation.

Fig. 347.



The sanitary applications of which charcoal is susceptible are numerous and important. It is employed, as has just been shown, in respirators, both to warm the air and disinfect it, as well as to purify the breath; in ventilation, to cleanse the air, to prevent the escape of various effluvia from graveyards, and from decomposing animal and vegetal matter, wherever and under whatever circumstances they may be met with. Thus it may be used with good effect in coffins, in the wards of hospitals, in dead-houses, in dissecting-rooms, in malarious districts, and, lastly, on the field of battle, where the work of disinfection has hitherto been left to the dog and the vulture, by which the process is far less efficiently performed.

Gum resins, benzoin, storax, olibanum, amber, mastic, cascarilla, and other bodies of similar nature, are, to some extent, disinfectants, but they do not remove smells already formed, they only disguise them. The rich, in the middle ages, concealed a want of cleanliness in their clothes and persons under a profusion of costly scents and essences; while now a want of freedom from filth is equivalent to insupportable misery and misfortune. Aromas seem to be less sought after where great cleanliness is observed, as there is nothing to mask, although they will always be partially employed, as many of them are so pleasing to the senses.

During epidemics, it has been the custom in all ages to use aromatic substances, and among these camphor has been strongly recommended in modern times as a preventive of disease. These have degenerated in many cases into mere amulets.

Sugar, also, may be said to be a disinfectant: if in the form of crystals or of a thick sirup, it does not readily change, and fruits are well known to be preserved by it. If put on meat, also, it causes it to long retain its freshness, probably by preventing ingress of air.

Anything which excludes the atmosphere is a preservative; consequently, by boiling food in tinned vessels, and suddenly closing them when filled with steam, a vacuum is formed on cooling, and the contents, whether animal or vegetal, are in this way kept in the greatest purity, so that they may be eaten after an indefinite length of time with as much relish as if they were perfectly new. This method has been adopted with the provisions supplied for exploring and other expeditions, as in the case of the lamented Sir John Franklin, and those who went in quest of him.

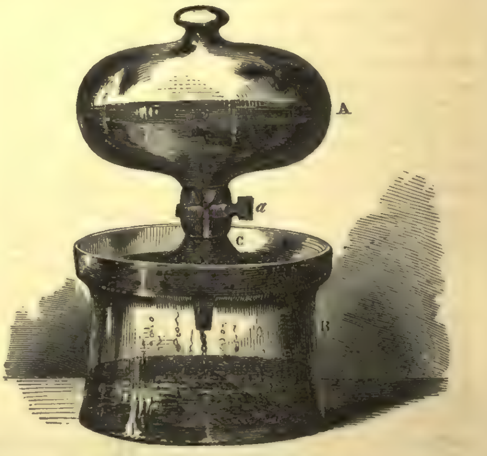
Metallic salts are disinfectants. Their bases unite with sulphide of hydrogen, thus destroying a very common and deleterious gas connected with most instances of putrefaction. Ledoyer recommended nitrate of lead, but it has not been much used, and lead is not only expensive but poisonous. Chloride of zinc has been extensively employed under the name of Sir William Burnett's Disinfecting Fluid, and acts very efficiently. Metallic salts are not, however, very pleasant, as they are destructive to clothing, are not readily washed off substances, and, being often acid, evolve disagreeable smells in a greater or less degree, especially when applied to manures. They are rather hurtful than valuable to vegetation, and can never be cheaply manufactured, the salts of iron and manganese excepted. Still, organic substances, as ropes, and portions of the rigging of ships, have been preserved under water for many years by means of chloride of zinc. Chloride of manganese was recommended by Mr. James Young of Glasgow, as, being the refuse of the chlorine manufacture, it was cheaply obtained. This is certainly the most economical method of obtaining a disinfecting metallic salt, but it has never been brought into the market, and the public generally use what is most readily obtained. Ellerman employed sesquichloride of iron, which was prepared for him by the Messrs. Muspratt of Liverpool, by dissolving burnt pyrites —sesquioxide of iron—in strong hydrochloric acid. The Editor is rather surprised that more of this compound is not used, as it is exceedingly cheap, and not dangerous, like the chloride of zinc; further, it acts most beneficially when mixed with excreted matters, immediately destroying effluvia.

Chlorine, as has been seen, has been tested as a disinfecting medium, and is a most powerful destroyer of all substances liable to undergo eremacausis, liberating the nitrogen in a gaseous state, breaking up ammoniacal, albuminous, and cyanogen compounds. When used in the form of hypochlorous acid, it is still more energetic.

Fig. 348 is a representation of a most ingenious and simple contrivance, for liberating any gas to which disinfectant powers are attributed.

To cause the evolution of chlorine, for example:—Having introduced the binoxide of manganese into the glass basin, B, put on the perforated wooden cover, C, fix the globular vessel, A, in the orifice, and pour a quantity of hydrochloric acid into it; then turn the stopper, *a*, and allow about a table-spoonful of acid to drop from the globe, upon which the gas will be set free, emanating through the holes in C.

Fig. 348.



When a further supply of chlorine is needed, it is merely required to again turn the stopper, and allow more acid to pass into the basin.

Chloroxide of calcium—well known as hypochlorite of lime, or bleaching powder—gives a fresh odor to meat which has become putrescent, and destroys all its decaying matter. It decomposes urea, and all the principles to be feared in animal refuse. But it is also destructive of those bodies which make the best manure, that is, those containing nitrogen; it must, therefore, never be brought into operation where their preservation is desirable, as in stables, *et cetera.* Its odor is not very agreeable; and the Editor, who worked for some months with it, found it had an injurious effect upon the lungs, so that it does as much evil as good; it appears that its chief value consists in the fumigation of rooms, and that while they are empty, as it would be deleterious to the patients. LABARRAQUE's disinfecting liquid, which consists of chloroxide of sodium, or hypochlorite of soda, has similar inconveniences, but is rather pleasanter.

Almost the same objections may be raised against nitrous acid which has been so celebrated, and for which Dr. CARMICHAEL SMYTH obtained from the government five thousand pounds. Its action is powerful, and it should be used only in the vacant rooms of hospitals and other places.

Chlorine and nitrous and nitric acids *destroy* sulphide and phosphide of hydrogen, uniting with the hydrogen, with separation of sulphur or formation of phosphoric acid; they and similar agents must therefore be superior to metallic salts. Some of the latter—as those of lead—are precipitated by the sulphide of hydrogen, and thus the sulphur is, so to speak, removed. Others—as the salts of iron and manganese—combine with it only under certain conditions, that is, if acid be not present.

None of the earths have very marked antiseptic qualities; those of magnesia are predominant over those of lime, and the former, when caustic, possesses the requisite properties in considerable force, its ordinary salts, however, acting very feebly.

Sulphurous acid—the fumes given off from burning sulphur—has, in all ages, been used as a disinfectant, and seems by general consent to be most valuable. Its action on animal and vegetal substances is well known to be such as to bleach them, and in doing so it appears to decompose the organic juice, and act deleteriously on animal life, as well as to produce a decided antifermentive and antiputrefactive effect. If injected into the veins in the state of sulphite of soda, it preserves the bodies entire, and is a complete embalmer. It has, however, such a penetrating and disagreeable odor, that it has not hitherto been generally used; but Dr. R. ANGUS SMITH and Mr. A. M'DOUGALL of Manchester have combined it with lime and magnesia, producing a disinfectant which is doubtlsss far superior to any hitherto fabricated. The extraordinary power of sulphurous acid to destroy the compounds of sulphur and phosphorus with hydrogen, so as to prevent their being again evolved, is made use of in this combination. It acts as a deodorizer, by removing smells already formed; it also performs the part of an antiseptic or antiputrescent, and impedes fermentation. One of the great advantages of a disinfectant is its power of destroying the smell of manure, at the same time preserving its most important ingredients. This can best be done by salts of magnesia, and their application for such a purpose was, some years ago, recommended by BOUSSINGAULT and Dr. ANGUS SMITH. When magnesia is united with sulphurous acid, the most effective, perhaps the only compound, capable of serving both ends, is then produced. Metallic salts have no beneficial action on manures: magnesia alone preserves the phosphoric acid and the ammonia. To the mixture already mentioned, a few per cents. of carbolic acid, or rather of carbolate of lime, are added; the latter has been found by experience to assist in destroying one portion of the odor with great rapidity. Being a fine, dry, white powder, it absorbs moisture in stables, *et cetera,* wherever it is deposited; metallic salts, on the contrary, must be in solution, and the wet is injurious not only to the hoofs, but also to the health generally of cattle. In the sick-room it is said to preserve the atmosphere, when sprinkled on offensive substances, in great purity. In the veterinary hospitals of barracks it has been proved to be very valuable.

The patentees have also proposed it as a precipitant for sewage water, and as a medium for disinfecting drains, and for this reason, among others, it is manufactured as a mixed sulphite of magnesia and lime, carbolate of lime, and lime; the latter favoring the precipitation. The salts formed have a most beneficial action on vegetation; even an excess of the disinfectant would produce this result, as the sulphites, though not very readily converted into sulphates when packed—not even when the mouth of the vessel is exposed to the atmosphere—are rapidly changed when spread over the ground.

After a careful trial of this disinfectant in this country, a quantity was ordered by Government to be sent on board every transport ship containing horses. A disinfectant, uniting efficiency, cleanliness, agreeable manipulation, and cheapness, in an equal degree with this, will not be easily found.

DYEING.—*Teinture,* French; *Färberei,* German; *Tinctura,* Latin.—Chemistry exhibits some of the most refined and ingenious of her applications in the various operations of dyeing and calico-printing. Though many processes in these arts were practised for ages before any correct views were entertained of the chemical nature of imbuing matters, yet dyeing is strictly a chemical art, and it cannot be properly understood without some acquaintance with the chemical properties of the acting bodies.

PARNELL, who has written one of the best works upon calico-printing, appositely remarks, that the great aim of all dyeing operations is the impregnation of a textile fabric with colored substances derived from animals, vegetals, and minerals, in such a manner as to render them intact by repeated affusions with water. The modes of effecting this object are as variable as are the tinctorial materials. Though the chemical reactions which are exhibited in the various dyeing and printing operations are, for the most part, sufficiently intelligible, yet they are sometimes highly complicated, and the theoretical principles of a few valuable processes, discovered accidentally, are even yet but imperfectly comprehended.

HISTORICAL NOTICE.—The art of dyeing has been successfully practised in the East Indies, Persia, Egypt, and Syria, from time immemorial. In the Pentateuch, frequent mention is made of linen cloths dyed blue, purple, and scarlet, and of rams' skins dyed red; and the works of the tabernacle, and the vestments of the high-priest, were commanded to be of purple.

The Tyrians were probably the only people of antiquity who made dyeing their chief occupation, and the staple of their commerce. The opulence of Tyre seems to have proceeded, in a great measure, from the sale of its rich and durable purple. It is unanimously asserted by all writers, that a Tyrian was the inventor of the purple dye, about 1500 years before the birth of **CHRIST**, and that the King of Phœnecia was so captivated with the color, that he made purple one of his principal ornaments, and that, for many centuries after, Tyrian purple became a badge of royalty. So highly prized was this color, that in the time of **AUGUSTUS** a pound of wool dyed with it cost, at Rome, a sum nearly equal to thirty pounds sterling. The Tyrian purple is now generally believed to have been derived from two different kinds of shell-fish, described by **PLINY** under the names *purpura* and *buccinum*, and was extracted from a small vessel or sac in their throats to the amount of one drop from each animal; but an inferior substance was obtained by crushing the whole substance of the *buccinum*. At first it is a colorless liquid, but by exposure to air and light it assumes successively a citron-yellow, green, azure, red, and, in the course of forty-eight hours, a brilliant purple hue. If the liquid be evaporated to dryness soon after being collected, the residue does not become tinged in this manner. These circumstances correspond with the minute description of the manner of catching the purple-dye fish given in the work of an eye-witness, **EUDOCIA MACREMBOLITISSA**, daughter of the Emperor **CONSTANTINE** the Eighth, who lived in the eleventh century. The color is remarkable for its durability. **PLUTARCH** observes, in his life of **ALEXANDER**, that, at the taking of Susa, the Greeks found, in the royal treasury of **DARIUS**, a quantity of purple cloth, of the value of five thousand talents, which still retained its beauty, though it had lain there one hundred and ninety years. This color resists the action even of alkalies and most acids. **HORACE** celebrates the Lacedemonian dye in the subjoined lines:—

> Nec Laconicas mihi
> Trahunt honestæ purpuras clientæ.

Which may be rendered—*No honorable lady-dependents spin Laconian purple for my use.*—**GAGE**, **COLE**, **PLUMIER**, **REAUMUR**, and **DUHAMEL**, have severally made researches with the coloring juices of shell-fish caught on various shores of the ocean, and have succeeded in forming a purple dye, but they found it greatly inferior to that furnished by other means.

PLINY states that the Tyrians gave the first ground of their purple dye by the unprepared liquor of the *purpura*, and then improved or heightened it by the liquor of the *buccinum*. In this manner they prepared their double-dyed purple—*purpura dibapha*—which was so called, either because it was immersed in two different liquors, or because it was first dyed in the wool and then in the yarn

In ancient Greece it does not appear that the art of dyeing was much cultivated. In Rome it received more attention; but very little is now known of the processes followed by the Romans, such arts being held, by them, in low estimation. The principal ingredients used by these people were the following:—Of vegetal matters, alkanet, archil, broom, madder, nutgalls, woad, and the seeds of the pomegranate, and of an Egyptian acacia; and of mineral productions, sulphate of iron, sulphate of copper, and a native alum mixed with the former.

The progress of dyeing, as of all other arts, was completely stopped in Europe, for a considerable time, by the invasion of the Northern barbarians in the fifth century. In the East the art still continued to flourish, but it did not revive in Europe until towards the end of the twelfth or the beginning of the thirteenth century. One of the places chiefly celebrated for this art was Florence, where, it is said, there were no less than two hundred establishments at work in the early part of the fourteenth century. A Florentine dyer, having ascertained in the Levant a method of extracting a coloring principle from the lichens which furnish archil, introduced this on his return, and acquired by its sale an immense fortune.

The discovery of America tended greatly to the advancement of this art, as the dyers were supplied thence with several valuable coloring materials previously unknown; amongst which are logwood, quercitron, Brazil-wood, cochineal, and annotta. About the year 1650 also, a great improvement in dyeing took place, which consisted in the introduction of a salt of tin as an occasional substitute for alum. With cochineal, the former was found to afford a color far surpassing in brilliancy any of the ancient dyes. To **CORNELIUS DREBBEL** the merit of this application is attributed. His son-in-law established an extensive dye-house at Bow, near London, about the year 1563.

For several centuries the Italians, and particularly the Venetians, prosecuted the art of dyeing to a large extent, and long held a complete monopoly of the art, and procured large sums by it from other nations. In the year 1548, one **JOHN VENTURA ROSETTI** published a book, termed *Plictho's Art of Dyeing*, in which he teaches how to give to cloth, linen, cotton, and silk, real and beautiful, as well as false and common dyes, which is, perhaps, the first book that ever appeared upon the subject, and laid the first foundation for the improvement of this art which afterwards took place; it having excited the French, English, and Germans to apply in earnest, in their different countries, to improving so useful and extensive a branch of manufacture.

After this period the art was extensively carried on by the Flemings, and many of them emigrating to Germany, France, and England, established themselves as dyers, and thus gave great impetus to its advancement. In 1667, a Fleming named **BRAUER** came to England with his whole family, and brought the dyeing of woollen there to that degree of perfection at which it has been ever since maintained. Shortly after this several works were published upon the art, which did much to improve it and make it more cultivated.

Logwood and indigo began to be employed as dyes in Europe about the middle of the sixteenth century, but not without considerable opposition from the cultivators of the native woad; the former were prohibited in England by Queen **ELIZABETH**, under a very heavy penalty, and all found in the country was ordered to be destroyed: their use was not permitted till the reign of **CHARLES** the Second.

Indigo, the innoxious and beautiful product of an interesting tribe of tropical plants, which is adapted to form the most useful and substantial of all dyes, was actually denounced as a dangerous drug—*food for the devil*, it was called—and forbidden by Parliament, in the reign of ELIZABETH, to be used. An act was passed, authorising searchers to burn both it and logwood in every dye-house where they could be found, and this act remained in full force till the time of CHARLES the Second, a period embracing a considerable part of a century. A foreigner might have supposed that the legislators of England entertained such an affection for their native woad, with which their denuded sires used to stain their skins in the olden times, that they would allow no outlandish drug to come in competition with it. A most instructive and interesting volume might be written, illustrative of the evils inflicted upon arts, manufactures, and commerce, in consequence of the ignorance of lawgivers.

When these absurd prejudices were gradually overcome in the eighteenth century, the art of dyeing made considerable progress. Madder, from which the color known as Turkey or Adrianople red is produced, then began to be properly appreciated; and quercitron, a fine yellow dye, was brought extensively into notice by Dr. BANCROFT. But the chief improvements of the moderns in this art consist in the employment of pure mordants, and in the application of colors derived from mineral compounds, as sesquioxide of iron, prussian-blue, chrome-yellow, chrome-orange, manganese-brown, *et cetera.* Each of these may be obtained as an insoluble precipitate, by mixing together two dissolved salts; in the dyeing processes, the proper solutions are made to mingle, and produce the deposit within the fibre by impregnating first with one solution and afterwards with the other. As the precipitate thus produced is imprisoned within the fibre, it is not removable by mere aspersion with water.

In India was discovered the mode of dyeing Turkey red, which is the most durable vegetal tint known. It was afterwards practised in other parts of Asia and in Greece; and about the middle of last century, dye-works for this color were established near Rouen and in Languedoc by several Greeks. In 1765 the French government, convinced of the importance of the process, caused an account of it to be published; but it was not introduced into England until the end of the eighteenth century, when a Turkey-red dye-house was established in Manchester by M. BORELLE, who obtained a grant from Government for the disclosure of his process. The method, which was made public, does not seem to have been very successful. A better mode was introduced into Glasgow about the same time by another Frenchman, named PAPILLON. Previous to this, however, Mr. WILSON of Ainsworth, near Manchester, had obtained the secret from the Greeks at Smyrna, which he revealed; but the process was said to be expensive, tedious, and less applicable to manufactured goods than to cotton in the skein. The greater part of the Turkey-red dyeing executed in Great Britain, is still carried on in Glasgow.

The ancients seem to have attained considerable proficiency in the art of topical dyeing, or of producing colored patterns on cloths. HOMER notices the linen cloths of Sidon as magnificent productions. In India the art of imparting a tinged pattern to cotton fabric has been practised with great success from a very remote epoch, and it derives its name of calico-printing from Calicut, a town in the province of Malabar, where it was formerly practised on an extensive scale. According to HERODOTUS, the inhabitants of Caucasus adorned their garments with representations of various animals by means of an aqueous infusion of the leaves of a tree; and the hues thus obtained were said to be so persistent, as to be incapable of being removed by washing.

PLINY gives an account of the nature of the process of topical dyeing practised by the ancient Egyptians, and it would appear that they attained such proficiency in the art, as could only have been originally acquired by extensive practice and close observation. He says:—An extraordinary method of staining cloths is practised in Egypt. They take white cloths and apply to them, not tints, but certain drugs which have the power of absorbing or drinking in color; and in the linen so operated on there is not the smallest appearance of any dye or tincture. These are then put in a caldron of some coloring matter, scalding hot, and after having remained a time are withdrawn, all stained and painted in various hues. This is indeed a wonderful process, seeing that there is, in the said caldron, only one kind of coloring material; yet from it the cloth acquires this and that color, and the boiling liquor itself also changes, according to the quality and nature of the dye-absorbing drugs which were at first laid on the white cloth. And these stains or colors, moreover, are so firmly fixed as to be incapable of being removed by water. If the scalding liquor was composed of various tinctures and colors, it would doubtless have confounded them all in one on the cloth; but here one liquor gives a variety of hues, according to the drugs previously applied. The colors of the cloths thus prepared are always more firm and durable than if the cloths were not dipped into the boiling caldron. In as few words, says PARNELL, *the principle of the common operations of calico-printing could hardly be described.*

The cotton chintz counterpanes of great size, called *pallampoors*, which have been manufactured in Madras from the earliest ages, have in like manner peculiar dye-absorbing drugs applied to them with the pencil, as also wax, to protect certain parts of their surface from the action of the dye, and are afterwards immersed in a staining liquor, which, when wax is applied, is usually the cold indigo vat, but without the wax is a hot liquor similar to the Egyptian. A dyer of Mulhausen lately brought home from India a rich collection of cloths in this state of preparation, which Dr. URE saw in the cabinet of the *Société Industrielle* of that interesting emporium of calico-printing. The native implements for applying the wax and coloring bases are placed beside the cloths, and form a curious picture of primeval art. There is, among other samples, an ancient *pallampoor*, five French yards long, and two and a half broad, said to be the labor of Hindoo princesses, which must have taken a lifetime to execute. The printing machinery of Great Britain has begun to supersede, for these styles of work, the hand labor of India. The topical dyeing of cotton goods seems to have been practised for a considerable time in Mexico. When CORTEZ conquered that country, he sent to CHARLES the Fifth cotton garments with black, red, yellow, green, and blue figures. The North American Indians have also been for a long time in possession of a mode of applying patterns in different colors.

Calico-printing does not appear to have been much practised in Europe until the close of the seventeenth or the beginning of the eighteenth century, when Augsburg became famous for its printed cottons and linens. From that city the manufactures of Alsace and Switzerland were long supplied with color-mixers, dyers, *et ceterâ*. The first print-ground in England was founded by a Frenchman on the banks of the Thames, near Richmond, and soon afterwards a more considerable one was established at Bromley Hall, in Essex. Several others were some time afterwards instituted in Surrey, in order to supply the London shops with chintzes, the importation of which from India had been prohibited by an act of Parliament, passed in 1700, on account of the excessive clamors of the silk and woollen weavers. Though merely intended as a protection to the English silk and woollen manufacturers, this act had the effect of greatly stimulating and increasing the infant art of calico-printing; for the demand for the printed calicos and chintzes could then be gratified only by printing in this country white Indian ones, the importation of which was still allowed under an impost. An excise duty of threepence per square yard was imposed on the printed calicos in 1712, which was increased in 1714 to sixpence; but the importation of calico being still considerable, a new alarm was raised, and a law enacted in 1720, which prohibited the wearing of all printed calicos whatever, whether of foreign or home production. The operations of the printer were then confined to those of linens.

The oppressive and absurd act of 1720 was repealed in 1730; but the calicos then permitted to be printed were to have the warp of linen and merely the weft of cotton, and were subjected to a duty of sixpence per square yard. With such discouragements, the progress made in calico-printing was extremely slow: so lately as the middle of the eighteenth century, it was computed that only fifty thousand pieces of the mixed cloth were printed annually in Great Britain; whereas, at the present time, several manufacturers turn out as much as three and four hundred thousand pieces per annum each. The part of the act of 1730, by which the warp was required to be made of linen yarn, was repealed in 1774; but the printed calicos were still subject to a duty of threepence halfpenny per square yard, the repeal of which, in 1831, has been of the utmost advantage both to the manufacturer and to the wearer.

The wonderful development which calico-printing has received within the last half century, is to be attributed, in great measure, to the adaptation of numerous ingenious mechanical inventions. The improvement in patterns, and the reduction in price, of cotton prints during this period, are striking illustrations of the advancement which has been made in machinery. The first improvement on the original wooden hand-printing block, which is quite similar to the block of a wood engraving, consisted in the substitution, for some styles of work, of copper plates, about three feet square—similar to those employed for printing engravings on paper—in which a much more delicate pattern could be cut than in wood. The color being laid on the copper plate, and the superfluous portion removed by a thin steel scraper, the plate was passed with the cloth through a press similar in principle to that of a copperplate printer.

The greatest mechanical improvement ever effected in this art was the invention of cylinder or roller printing, which is said to have been first made at Jouy, in France, by a calico-printer named OBERCAMPF, in whose hands alone it remained for some time. The invention appears also to have been independently made by a Scotchman named BELL, and was first successfully applied on the large scale at Monsey, near Preston, about the year 1785. Cylinder printing has been most fully developed in Lancashire, and the perfection to which it has been there brought is the chief cause of the admitted superiority of the calico-printing establishments of Great Britain over those on the Continent, where the cylinder is comparatively but little used.

Printing by this method is executed not only with greater accuracy than by the wooden block, but with an almost incredible saving of time and labor. A single cylinder machine, with one attendant to regulate the rollers, is capable of printing as many pieces as a hundred men and the same number of girls could do with the hand-block in the same time; or as much work may be executed by the cylinder machine in four minutes, as by the ordinary mode of block-printing in six hours. A length of calico equal to one mile has been printed with four different colors in one hour!

The successful application of an engraved copper cylinder was followed by that of a wooden roller having the pattern in relief, the mode of impressing patterns by which is known as *surface-printing*. The *union* or *mule machine*—a combination of the engraved copper cylinder with the wooden roller in relief—was contrived about 1805 by Mr. JAMES BURTON, of Church, near Blackburn.

During the last century, the chemical principles of dyeing and calico-printing were investigated by BERGMANN, BERTHOLLET, DUFAY, HELLOT, and MACQUER, and improvements, both numerous and valuable, were suggested by their researches. The application of chlorine by BERTHOLLET to the bleaching of tissues, especially cotton and flax, contributed in no small degree to the advancement of these arts. It is during the present century, however, and from the inquiries and examinations of numerous living chemists, that they have received the most essential assistance from chemical science.

The chief improvements of the moderns consist, as already observed, in the employment of colors derived from mineral substances. Among the earliest of this class of bodies used were *iron buff* and Scheele's green, which were followed by antimony-orange—first applied by Mr. MERCER—and prussian-blue. The two chromates of lead—chrome-yellow and chrome-orange—were next introduced by M. KŒCHLIN, of Mulhausen, in 1821, and a few years afterwards Mr. MERCER first applied, on the large scale, the binoxide of manganese, known as manganese bronze.

ORGANIC COLORING MATTERS.—Under this head is included a variety of substances of very different characters and composition. Many of them are extremely important in the arts; such, however, as are employed in dyeing and calico-printing only, will be here noticed.

ALKANET—*L'Orcanette*, French; *Orkanet*, German, —the root of the *Anchusa tinctoria*, which grows in the Levant, and some other warm countries. It was used by the ancients as a dye, or as a groundwork to those stuffs which were to be dyed purplish-red. The ladies, in ancient times, also used it as a paint. Some years ago it was introduced anew as a dye, but only with partial success. Its coloring matter, *anchusin* or *anchusic acid*, which has been examined by JOHN and by PELLETIER, has the characters of a resin; it is dark-red, softened by heat, insoluble in water, soluble in alcohol, and very much so in ether, fat, and volatile oils, to all of which it imparts a brilliant red hue. When an alcoholic or ethereal solution of anchusin is mixed with water and boiled, it gradually becomes brown. The red color primarily changes to a bluish green, and a black substance remains on evaporation to dryness, soluble in water and in alcohol; the latter solution is reddened by chlorine, rendered grey by acids, and blue by alkalies; protochloride of tin occasions a crimson, subacetate of lead a blue precipitate; salts of iron give a dark-violet, and chloride of mercury a flesh-colored precipitate.

To obtain anchusin, all the soluble matters are first abstracted from the bruised root by water; it is then digested in a solution of carbonate of potassa, from which it may be readily precipitated by an acid. It may likewise be procured by carefully digesting the alcoholic extract of the root in ether, and evaporating the solution on a water-bath.

According to PELLETIER, its composition is—

		Centesimally represented.	
	Atomic weight.	Theory.	Pelletier.
17 Eqs. of Carbon,.....	102	70·83	71·178
10 Eqs. of Hydrogen,..	10	6·94	6·826
4 Eqs. of Oxygen,....	32	22·23	21·996
1 Eq. of Anchusin,..	144	100·00	100·000

A variety of shades of lavender, lilac, violet, *et cetera*, are dyed by means of alkanet, but caution and experience are necessary to insure success, and the hues are easily affected by light, a great barrier to its use. Formerly, colors were generally dyed with it by giving the cloth a soap or oil preparation, the former being combined with alumina to serve as the base.

ALOES — *Aloès*, French; *Aloe*, German; *Aloe*, Latin—is the produce of several species of *aloe*, especially *Aloe vulgaris*, *socotrina*, and *spicata*. The plant is a native of the East Indies and Barbary, and is cultivated in the West Indies, Italy, Sicily, and Malta. The finest quality is obtained by evaporating the juice which exudes spontaneously from the transversely cut leaves. The latter, by boiling, yield a common variety.

Dr. BANCROFT first recommended aloes as a dyeing agent—for which it has since been occasionally more or less used—and proposed its digestion in nitric acid, as the mode of its preparation. It is soluble both in alcohol and in boiling water, the latter solution depositing, on cooling, a pulverulent brown substance taken up on re-boiling the menstruum, and which has been erroneously denominated *resin* of aloes. Its solubility in water at a temperature of 212°, shows that it is not a resin; it dissolves in the alkalies and in lime-water, and is thrown down from these solutions by acids.

Aloetin—obtained by making a cold infusion of aloes and evaporating to dryness—is regarded as the purgative as well as the bitter principle of aloes, of which it constitutes about sixty per cent. According to ROBIQUET, aloetin should be regarded as *coloring matter*, combined with a small amount of ulmate of potassa, phosphate, sulphate, and carbonate of lime, gallic acid, and vegetal albumen. When freed from albumen, it contains no nitrogen, and its composition is—

	Centesimally.
Carbon, ...	27·39
Hydrogen,.............................	11·11
Oxygen, ...	61·50
	100·00

If aloes be subjected to dry distillation, or heated with caustic potassa, it affords abundance of ammonia, so that it contains nitrogen, but neither its proximate nor ultimate composition has yet been satisfactorily studied. When the *cold* aqueous infusion of aloes is evaporated, a brown transparent residue is obtained, readily soluble in water and alcohol, but less so in ether. Its watery solution, which has not an acid reaction, yields a resinous deposit when treated with sulphuric acid. This aqueous infusion of aloes—prepared without heat—gives a brown precipitate with acetate of lead, and when this has been separated by filtration, the basic acetate occasions a fresh deposit in the filtrate. Alkalies and the sesquisalts of iron darken the tint of this extract.

A patent was taken out in 1847 for certain applications of aloes to dyeing, of which the following is a brief description:—

The mode of preparing the coloring matter from aloes is as follows:—Into a boiler or other vessel, capable of holding about a hundred gallons, the patentee puts ten gallons of water, and one hundred and thirty-two pounds of aloes, and applies heat until the latter is dissolved. Eighty pounds of nitric or nitrous acid are then added in successive small portions, to avoid the evolution of such a quantity of nitrous gas as would throw part of the contents out of the boiler. When the whole of the acid has been introduced, and the disengagement of gas has ceased, ten pounds of a solution of caustic soda or potassa, of about 30°—specific gravity 1·15—are added, to neutralize any acid which might remain undecomposed in the mixture, and to facilitate the use of the aloetic compound in dyeing and printing. If required in a dry state, the whole may now be incorporated with one hundred pounds of China clay, and dried by means of stoves, or in a current of air.

The coloring matter is used in dyeing by dissolving a sufficient quantity in water, according to the shade required, adding as much hydrochloric acid or commercial tartar as will neutralize the alkali, and slightly acidulate the dye-bath. When it is required for printing, it is dissolved in water in such proportion as will produce the requisite tint; the solution is thickened with gum or other agent employed for such purposes, and hydrochloric acid, or tartar, is added for the same ends as have just been mentioned.

ANNOTTA.—*Roucou*, French; *Orleans*, German.—This substance is obtained from the pulp of the seeds of the *Bixa Orellana*, a shrub native of South America, but cultivated in Guiana, St. Domingo, and in the East Indies.

It is said to be obtained from the seeds by rasping or grinding them, adding water, and suffering the mixture to putrefy or ferment; the pulp is then strained through sieves, and boiled down to the consistence of a paste. LEBLOND, who imported the seeds into France, found this tedious process unnecessary, owing to the coloring matter lying wholly on the surface of the seeds, whence it was speedily removed by the solvent power of water, and could then be precipitated by a weak acid, and dried in the usual way. The experiments made by VAUQUELIN on the seeds, confirmed the efficacy of this method, and the dyers found that the annotta thus obtained was worth at least four times that of commerce; that it was more easily employed, required less solvent, and, finally, occasioned less trouble in the copper, and furnished a purer color.

Annotta is a pasty substance, of a deep orange-red hue, nearly tasteless, but having a disagreeable odor, owing to its being occasionally moistened, in the warehouses, with urine. When heated, it softens, burning with much flame and smoke, and leaving a bulky, brilliant coal. It is only partially soluble in water, but alcohol and ether act readily upon it, and form solutions which, when evaporated, give the coloring matter in a pulverulent state. The alkalies and their carbonates soon dissolve it, forming dark-red menstrua, in which acids occasion an orange-red precipitate. Neither hydrochloric nor acetic acid has much action on annotta, but with sulphuric acid it is resolved into a blue liquid, which gradually passes into green and violet. When mixed with nitric acid there is violent action, and even inflammation. It dissolves in turpentine and the fixed oils; forms with alumina an orange-colored, with protoxide of tin a citron-yellow, and with oxide of copper a greenish-yellow compound. It is used to dye silks golden-yellow, by simply digesting them in its alkaline solution; and orange-red, by afterwards exposing them to the action of a dilute acid. It is also employed to dye cotton yellow, with aluminate of potassa as a mordant.

It is extensively used for dyeing of woollen and silk various hues, and forming the ground of different colors, such as scarlet. Its use for dyeing of cotton is now very limited; its color on that stuff is very fugitive and changeable by air, sunshine, or any substance having acid or alkaline reactions.

ARCHIL.—*Orseille*, French; *Persio*, German.—A violet-colored paste prepared from different species of lichens, amongst which *Roccella tinctoria*, *R. corallina*, *Lecanora tartarea*, *Variolaria lactea*, and *V. dealbata*, have been especially resorted to. Many native lichens, however, which grow more or less abundantly on the British shores, might, with advantage and economy, be substituted for the somewhat expensive and scarce foreign Roccellas, and other dye-lichens usually employed for the manufacture of archil, cudbear, and litmus.

The synonymy or nomenclature of these dyes has not only given rise to great confusion as to their nature, origin, and uses, but leads to the idea that they are three distinct substances, having a separate composition, source, and economical application. For all ordinary or practical purposes, they may be looked upon as essentially the same coloring matter, differing slightly in tint, consistency, or applicability to certain fabrics, according to modifications in the process of manufacture.

Archil may be regarded as the English, *cudbear* as the Scotch, and *litmus* as the Dutch name for one and the same substance; the first being generally fabricated in the form of a liquid of a beautiful reddish or purple hue, the second chiefly in that of a powder of a lake or red color, while the third is in that of small blue parallelopipeds or cakes. The latter variety differs in the greatest degree from the others in color and consistence; its tinge is imparted by the addition of some alkaline carbonate, as that of potassa, soda, or lime, and sometimes —as an adulteration—of indigo; and its consistence by the presence of thickening agents, such as gypsum, starch, chalk, or various silicious and argillaceous matters.

Archil, cudbear, and litmus are now manufactured in England, either from the same species of dye-lichen, or from a variety of kinds, by altering the process of fabrication: in other words, either the *same* dye, which may be *red*, *purple*, or *blue*, and in the form of a *fluid*, *paste*, *powder*, or *cake*, may be prepared from *different genera of lichens*—or *distinct dyes*, having peculiar characters, may be produced from the *same* or from different species, according to very slight variations in the mode of treatment.

Moreover, the physical characters of the dyes prepared from the roccella, lecanora, or other lichens usually employed in the manufacture of these three coloring matters, on the small scale, are identical or indistinguishable.

GÉLIS, many years ago, made a series of experiments with a view to determine whether any or all of the lichens, used in the manufacture of archil and cudbear, were not equally serviceable for the preparation of *litmus*, with an affirmative result; and PEREIRA mentions that it may be variously made from Roccella tinctoria, Roccella fuciformis, Lecanora parella, Isidium corallinum, Variolaria orcina, or from any of the species capable of yielding archil or cudbear. The latter distinguished authority was also informed by an archil-maker, that he was in the habit of manufacturing *litmus* from *pipe-clay*, *starch*, *soda*, and *common archil-liquor*. —*Dr. W. Lauder Lindsay.*

The lichens, which are principally collected on rocks adjacent to the sea, are cleaned and ground into a pulp with water; ammoniacal liquors, chiefly derived from gas-works, or occasionally from urine, are from time to time added, and the mass is frequently agitated, to expose it as much as possible to the action of the atmosphere. Peculiar principles existing in the lichens are, by the joint instrumentality of the air, water, and ammonia, so changed as to generate coloring matter, which, when perfect, is expressed, and chalk, plaster of Paris, or other substance, is added to it, till a sufficient consistency is attained.

The lichens have been of late years subjects of numerous interesting, but intricate, chemical investigations, and a number of new compounds have been isolated, as *lecanorin*, from *Lecanora*, from which colorless substance, by the influence of ammonia and the air, a purple-red is produced. From *Parmelia ocella* and *tartarea*, as also from other lichens, *erythrin* and *erythrylin* have been formed. *Orcin* and *orcein* are somewhat analogous products, also crystallizable, obtained from the *Varioluria dealbata* by decomposition of the lecanorin.

KANE states, as the results of his researches several years ago—There exist in the lichens which yield purple colors, at least two groups of colorific matters, characterized by different active principles, but ultimately generating, by their decomposition, the *same* colored substances, the *archil* from these various lichens being for the purposes of the arts, *identical*, and containing in reality the same body—orcein. Dr. LINDSAY says—The chemical character of such coloring matter is not persistent, its chemical constituents are in a constant state of change; hence they differ in composition at various stages of the manufacture of the dye, corresponding to variations in color. The red or purple tint, as usually exhibited in common archil, appears to be the ultimate or most permanent stage. The blue hue is exhibited at an intermediate period, and, while it is very beautiful, it is also very delicate and fugacious, passing rapidly and readily into red on exposure to the air, and on contact with the weakest acids, *et cetera.* For instance, blue archils, on being spread on paper, or otherwise subjected to atmospheric action, almost immediately lose their beautiful blue color and bloom, assuming a distinctly red tint. The azure tint can only be preserved by the addition of potassa, soda, lime, or of alkaline salts. In most of the dye-lichens, the chemical changes involved in the conversion of the colorless colorific principles into colored compounds, are of a somewhat complex character, but, in general terms, they appear to consist essentially in their oxidation, either directly, or by intermediate steps, into orcein, or some chemically analogous principle—which appears to be the basis of the beautiful purple or red hue.

The infusion of archil is crimson, bordering on violet. As it contains ammonia, which has already modified its natural color, the fixed alkalies produce little change in it, only slightly deepening the hue, and rendering it more violet. Alum forms in it a brown-red precipitate, and the supernatant liquid retains a yellowish-red color. The solution of tin affords a reddish precipitate, falling down slowly, the filtrate from which is feebly red. Other metallic salts produce precipitates, but which offer nothing remarkable.

The coloring principle of archil is soluble in water and alcohol, and its tinge is changed, by the weakest acids, from purple or violet to a bright red. It is a brilliant, but not permanent dye, and is chiefly used to give its own rich and peculiar color as a finish to silks and woollen cloths already dyed. It is rarely used for cotton goods.

Mr. LEESHING has found that archil is sometimes sophisticated with logwood extract. He states that, as a test for this adulteration, dyeing a strip of calico mordanted for madder red or chocolate is not altogether satisfactory, and chiefly because archil itself is fixed in this way to some extent, particularly when the mordant is somewhat concentrated.

When the amount of logwood extract in archil is considerable, it will be indicated, on the addition of alum or protochloride of tin, by the shade produced, as compared with pure archil treated in the same manner. These reactions, however, are not decisive, and are of value only when taken together with others.

When about fifty drops of pure archil, diluted with three ounces of water, and slightly acidified by means of acetic acid, are mixed with fifty drops of fresh solution of protochloride of tin—one part of the salt in two of water—and heated in a flask upon a sand-bath, the color is almost entirely destroyed when the liquid is at the boiling point, presenting only a yellowish tinge.

A drop of logwood extract, diluted with three ounces of water, and treated in the same manner, produces a distinct violet, which remains unaltered after several hours' boiling.

This violet color produced by logwood extract, is somewhat modified by a large proportion of archil; but it has been found that it is capable of indicating the presence of logwood, even when it does not amount to more than three or four per cent. of the archil. The boiled liquid has then a permanent grey tint.

When the adulterating substance is extract of Lima- or Sapan-wood, the boiled liquid retains a red hue.

The color of the archil is gradually restored, in what has been submitted to ebullition, by exposure to the air, and by the addition of alkali, while, on the contrary, the color produced by logwood is destroyed only by an alkaline solution of tin, and is restored by acids.

Blue archil, when mixed with a small quantity of ferrocyanide of potassium, acquires all the properties of the red. The presence of the ferrocyanide does not interfere with the above method of testing for wood extracts.

Archil and cudbear are extensively used in dyeing woollen for a great many colors, as purple, lavender, lilacs, also in browns, chocolate, *et cetera.* It is also used for silk, for several tints of lavender, violets, and as a ground for crimsons, *et cetera;* but it is not used for cotton, having no affinity for that fibre.

BARBERRY ROOT.—The barberry tree, *berberis vulgaris*, grows in almost every part of the world, and large quantities of it are obtained from India, where it vegetates abundantly, and attains great perfection.

The root yielded 2·55 of brown coloring matter, precipitable by acetate of lead; 6·62 of a fine yellow extract, not so thrown down; gum, 0·35; starch, 0·20; oil, 0·40; soft resin, 0·55; lignin, 55·40; water, alkaline earthy salts, *et cetera*, 33·93.

The yellow coloring matter—*berberin*—first isolated by BUCHNER and HERBERGER, is found in the whole of the root, and near the bark of the stem. It is much used in staining leather, but has not yet been so extensively employed in the dyeing of cotton as it seems to merit.

To procure berberin in a pure state, the root is exhausted by boiling water, and the decoctions concentrated to the consistence of extract, which is repeatedly digested in alcohol of specific gravity 0·844, as long as that fluid acquires a bitter taste. These tinctures are then filtered, and a considerable portion of the alcohol having been distilled off, the residue is allowed to crystallize in an open vessel, placed in a cool situation. The resulting crystals having been freed from the supernatant liquor, and slightly washed with cold water, are dissolved in a small quantity of that menstruum heated to 212°, and allowed to re-form. The process is completed by dissolving the crystals in boiling alcohol, from which they are again deposited, on evaporation, in a crystallized form.

When thus prepared, berberin is in delicate, silky, bright yellow, inodorous, but intensely bitter crystals, which require five hundred parts of water at 50° for their solution, but are soluble in any proportion in the same liquid in a boiling state. They dissolve in two hundred and fifty parts of cold, but in much less of boiling alcohol, and are neither acid nor alkaline. If heated to 212°, berberin acquires a reddish tint, but assumes its former color on cooling; it fuses at 265°, and at a higher temperature emits the odor of burnt horn, and leaves a carbon difficultly combustible. When dissolved in cold nitric acid, abundant fumes are evolved, and a deep red liquor is formed, which loses color on being heated, and then contains oxalic acid. When subjected in a dry state to the action of chlorine, it acquires a blood-red hue, and becomes more soluble in water; but if this gas be passed through an aqueous solution of berberin, a brown substance is thrown down, soluble in alkali, whence it is precipitated by acids. Sulphuric acid dissolves it, and on dilution a brown deposit is occasioned, insoluble in water and alcohol, but dissolving in alkalies. Infusion of galls causes a brown subsidence in solutions of berberin.

When berberin, dissolved in warm water, is added to solutions of the metallic salts, its combinations with the oxide of the metal are thrown down. These precipitates are yellow, with the salts of manganese, cobalt, antimony, tin, mercury, and silver, green with those of copper and nickel; orange-colored with the chlorides of iron, gold, and platinum, and with the nitrate of bismuth; the salts of lead, zinc, and protoxide of iron afford no definite results.

Berberin acts in a peculiar manner upon some of the haloid salts; if its warm aqueous solution be added to one of bromide or iodide of potassium, a bulky pale-yellow deposit occurs; the precipitate with cyanide of potassium is orange-colored, and is soluble in water; those produced by ferrocyanide, sulphocyanide, and sulphide of potassium are, respectively, green, pale-yellow, and brown.

The formula assigned to berberin when dried at 212°, is $C_{33}\,H_{18}\,O_{12}\,N$, its composition being—

			Centesimally.	
			Theory.	Buchner.
33	Eqs. of Carbon,.....	198	60·74	61·23
18	Eqs. of Hydrogen,..	18	5·52	5·49
12	Eqs. of Oxygen,.....	96	29·45	29·25
1	Eq. of Nitrogen,...	14	4·29	4·03
1	Eq. of Berberin,....	326	100·00	100·00

According to FLEITMANN, berberin, which is represented by BUCHNER as being a weak acid, forms crystallizable compounds with the acids; he therefore regards it as an organic base, and assigns to it the formula $C_{42}\,H_{18}\,O_{9}\,N$.

Linen, cotton, wool, and silk may be dyed with berberin without the intervention of bases, but if it be combined with tin, the colors will be more brilliant and permanent.

BARWOOD is brought principally from Sierra Leone. It has been examined by Messrs. GIRARDIN and PREISSER only, who consider its coloring principle to be essentially the same with that of sandal, or, as it is more commonly called, saunders-wood.

This wood, say the above-named authorities, when in the state of a coarse powder, is of a bright red color, without any odor. It imparts scarcely a tinge to the saliva. Cold water, in contact with it, merely acquires a fawn tint after five days' maceration; one hundred parts of water only dissolve 2·21 of matter, consisting of 0·85 coloring principle, and of 1·36 saline compounds. Boiling water becomes more strongly imbued of a reddish-yellow, but, on cooling, it deposits a portion of the coloring matter as a red powder. One hundred parts of water at 212° dissolve 7·24 coloring principle and 1·62 salts, principally sulphates and chlorides. On macerating the powder with strong alcohol, the liquid almost immediately becomes of a dark vinous-red. To remove the whole of the color from fifteen grains of the wood, it was necessary to treat it several times with boiling alcohol, which eventually removed 0·23 of coloring matter, and 0·004 inorganic salts: barwood contains, therefore, twenty-three per cent. of a red principle, whilst saunders-wood, according to PELLETIER, has only 16·75 per cent.

The alcoholic solution behaves in the following manner towards reagents:—Distilled water, added in great quantity, produces a considerable yellow opalescence, which is redissolved by the fixed alkalies, the liquor acquiring a dark vinous hue. The fixed alkalies and lime-water turn it dark crimson or violet. Sulphuric acid heightens the color to a cochineal-red. Sulphide of hydrogen acts like water. Chloride of tin produces a brick-red, and acetate of lead a dark-violet gelatinous precipitate. Salts of the protoxide of iron give very abundant violet, and copper salts violet-brown gelatinous deposits. Chloride of mercury throws it down, in large quantity, of a brick-red; sulphate of zinc occasions a flocculent bright red, tartar-emetic an abundant dark cherry, and baryta-water a violet-brown precipitate, while nitrate of bismuth imparts a light and brilliant crimson-red to the solution. Neutral salts of potassa act like pure water. Gelatin produces a brownish-yellow ochreous compound. Chlorine lowers the color of the liquid to light yellow, with a slight yellowish-brown precipitate, resembling hydrated sesquioxide of iron.

Pyroxilic spirit acts on barwood like alcohol, and the strongly-colored solution behaves similarly towards reagents. Hydrated ether almost immediately acquires an orange-red tint, rather paler than that with alcohol, and takes up 19·47 per cent. of coloring principle. Potassa, soda, and ammonia, in contact with powdered barwood, assume an intensely violet-red color, and on being neutralized with hydrochloric acid deposit the coloring matter in the form of an obscure reddish-brown powder. Acetic acid becomes of a dark-red hue, as with saunders-wood.

Barwood is never used for silk dyeing; it is often used along with other woods in dyeing woollen brown, and other dark mixed tints; but it is extensively used for dyeing a rich and permanent red upon cotton yarn, the goods being wrought for some time in a hot decoction of sumach, then in a solution of protochloride of tin, out of which it is washed, first in cold, and then in hot water; the yarn is then wrought in a boiler at a boiling heat along with the ground wood, by which means a brilliant red is obtained.

BRAZIL-WOOD.—*Bois de Pernambouc*, French; *Brazilienholz*, German.—There are several varieties of this wood, distinguished from one another by the name of the locality where they are obtained, as Pernambuco, Santa Martha, Sapan, *et cetera*. By the dyers they are often all named peach-wood, from an inferior sort much in use, and procured from Campeachy.

The Brazil-wood tree, botanically termed *Cæsalpinia crista*, is a production of America, and is stated, by many authorities, to have given the name to the country in which it grows—Brazil. The Portuguese government early discovered its value, and made it a royal monopoly; hence was derived its obsolete and nearly forgotten name of *Queen-wood*. It mostly vegetates in dry places, and amongst rocks; its trunk is large, crooked, and knotty.

The wood known in commerce as Pernambuco contains a larger amount of coloring matter than the others, and is most esteemed. It is hard, and is yellow when newly cut, but becomes red on exposure to the air. Lima-wood is much the same in quality. Sapan-wood grows in Japan, and stands next in value to the two before mentioned. It is not abundant, but is much prized for a certain shade of red, affording a clear, fine color. Lima-wood, as imported, gives about 2·7 per cent., while Sapan-wood yields only 1·5 per cent. of ash: in both lime is most prevalent. Peach, or Nicaragua, sometimes called Santa Martha-wood, is still inferior, but for some purposes is preferred, although the amount of coloring principle is not so great.

Brazil-wood is distinguished from logwood by its paler color, and by the precipitates which it gives with acetate of lead, protochloride of tin, and lime-water, which, instead of being violet as with logwood, are crimson. Both their infusions are rendered yellow by the addition of one or two drops of hydrochloric or sulphuric acid.

CHEVREUL applied the term *Brazilin* to the coloring matter of these woods, but PREISSER designates by the same name a colorless, crystalline substance, which passes into the true coloring principle by oxidation, and which he has denominated *Braziléin.*

PREISSER obtained brazilin by making a concentrated alcoholic solution of the wood, agitating the menstruum with hydrated oxide of lead, decomposing the metallic salt so formed by sulphide of hydrogen, filtering and evaporating the colorless liquid, which affords small acicular crystals, having primarily a sweetish, but, subsequently, a slightly bitter taste, and composed of—

			Centesimally represented.		
			Theory.		Preisser.
36 Eqs. of Carbon,.....	216	....	66·25	....	65·498
14 Eqs. of Hydrogen, ..	14	....	4·29	....	4·324
12 Eqs. of Oxygen, ...	96	....	29·46	....	30·178
1 Eq. of Brazilin, ...	326	....	100·00	....	100·000

Brazilin is soluble in alcohol and ether; hydrochloric acid, with access of air, colors it of a brilliant red, sulphuric acid dissolves it with a yellow hue, which soon changes to black; when heated with dilute nitric acid it is reddened very considerably, ruddy vapors are evolved, and oxalic acid is formed. The action of chromic acid and of alkaline chromates is remarkable, and tends to explain several important applications in calico-printing. On placing chromic acid, or finely powdered bichromate of potassa, in contact with a concentrated solution of brazilin, lively effervescence ensues, and a considerable quantity of formic acid may be collected by distillation. At the same time the liquid assumes a brownish-red color, which gradually becomes deeper, and, in a few hours, a very dark crimson lake separates. This, according to PREISSER, consists of the modified coloring principle braziléin, with oxide of chromium. It is not very stable, for a few washings with water, slightly acidulated with hydrochloric acid, remove the whole of the color, leaving behind pure oxide of chromium.

The moist crystals of brazilin gradually acquire a dark-red purple tint on being placed under a large bell-glass, near a capsule containing caustic ammonia. By pouring the latter upon the crystals, the coloration is immediately produced.

In contact with the air, potassa and soda communicate to brazilin a vinous blood-red hue, which is precipitated by hydrochloric acid in the course of an hour.

A solution of brazilin is reddened by lime-water; when this menstruum is filtered through paper unwashed with acid, the paper, some time after, assumes a bright scarlet hue. Nitrate of silver, and chloride of gold, on being boiled with brazilin, are reduced. Acetate of lead produces a yellowish-white precipitate, which becomes brown on desiccation.

When a solution of brazilin is heated with sulphuric acid and binoxide of manganese, in an apparatus so arranged as to collect both fluid and gaseous products, a violent agitation is manifested in the liquor; no gas is evolved, but formic acid is present in the distillate. The liquid in the retort is strongly red; left to spontaneous evaporation, protosulphate of manganese is deposited, and the supernatant fluid contains the same modified coloring matter as that obtained with chromic acid.

An aqueous solution of brazilin keeps for a considerable time without undergoing any change; it subsequently becomes yellow, and at the margin brilliant red. This mutation is produced more rapidly on boiling the solution; on allowing it to evaporate, it deposits very beautiful, radiant, red needles of a satiny lustre —brazilêin. The change is represented by Preisser thus:—

1 Eq. of Brazilin,................	$C_{36} H_{14} O_{12}$
2 Eqs. of Oxygen,..................	O_2
1 Eq. of Brazilêin,................	$C_{36} H_{14} O_{14}$

Chevreul originally obtained brazilêin by dissolving an aqueous extract of the wood in water, and agitating the menstruum with oxide of lead; the liquor was then decanted from the precipitate, evaporated to dryness, and the residue digested in alcohol; this solution, on being filtered and evaporated, yielded the brazilêin. Preisser procured it, however, by the oxidation of brazilin, as above shown, and ascertained its composition to be as under:—

		Centesimally represented.	
		Theory.	Preisser.
36 Eqs. of Carbon,.....	216	63·16	63·324
14 Eqs. of Hydrogen,..	14	4·09	3·967
14 Eqs. of Oxygen,....	112	32·75	32·709
1 Eq. of Brazilêin,....	342	100·00	100·000

Brazilêin, as isolated by Chevreul, is in very small orange-colored crystals, which dissolve in ether, alcohol, and water, forming red menstrua, which, with sulphuric, nitric, and hydrochloric acids, are changed to a dirty, but, with phosphoric and citric acids, to a bright and permanent yellow. The aqueous solution of brazilêin, and paper tinged with it, are changed by the alkalies, and by salts of lead and tin, to a purple, and alum produces a red precipitate.

Precipitates obtained by this means are extensively used for dyeing and staining of paper for walls. The solubility of the coloring matter of Brazil-wood gives it a suitability over barwood for many purposes, and makes its use much more general, being used for every kind of fabric; and the strong affinity of the coloring matter for the various oxides used as mordants, gives it a most extensive range of application both in dyeing and calico-printing. The making of strong decoctions of this wood along with a few others for calico-printers, is an important branch of manufacture at the present day.

Camwood is another species of red wood used in the dye-house, and is imported from Sierra Leone. The color obtained from it is said to be more permanent, and in many instances to exceed in beauty that obtained from Brazil-wood. The precipitates from a decoction of camwood are more yellow than those afforded by Brazil-woods, and it appears to contain more tannin, and to be less affected by alkalies. Sulphate of iron produces, in its solutions, a brownish-black precipitate; protosalts of tin impart to the menstruum a bright carmine-red color, but little precipitate; lead salts throw down a rich orange, and nitrate of silver a reddish-yellow precipitate. Alum gives a beautiful red hue.

This wood may also be used for browns and other composition colors where Brazil-wood is commonly employed; indeed, it may be taken as a substitute for the latter in many instances, as it is more soluble in water, besides possessing many other advantageous properties.—*Napier.*

Catechu—*Cachou*, French; *Kaschu*, German; *Catechu*, Latin—is an extract of the Khair-tree—*acacia catechu* or *mimosa catechu*—of Bombay, Bengal, and other parts of India. It was long regarded as of earthy origin, and bore the name of *terra Japonica*, or Japan earth.

As soon as the trees are felled, the whole of the exterior white wood is carefully removed, and the interior colored portion cut into fragments, which are placed in narrow-mouthed unglazed pots, and water added in sufficient quantity to cover them. Heat is then applied and maintained till the decoction is half evaporated, when, without being strained, it is transferred to a shallow earthen vessel, and further reduced two-thirds by boiling. It is next left at rest in a cool situation for a day, and is afterwards evaporated by the heat of the sun, being occasionally stirred during that time. After acquiring sufficient solidity, it is spread upon a mat or cloth, which has been previously covered with the ashes of cow-dung, and this mass, divided by means of a cord into cubical pieces weighing four or five ounces each, is completely dried by exposure to the air, and is then ready for sale.

There are different qualities of catechu in the market, varying considerably in their value for dyeing purposes. That from Bengal occurs in flattish round lumps of a light-brown color outside, but dark internally. It contains vegetal detritus, has a dull fracture, and its specific gravity is 1·28. It consists, according to Sir Humphrey Davy, of—

	Centesimally represented.
Tannic acid,..........................	48·5
Extractive matter,.....................	36·5
Mucilage,..............................	8·0
Insoluble matters—silica and lime,........	7·0
	100·0

Bombay catechu is in square masses, the method of making which has already been noticed. Its color is reddish-brown, the texture uniform, and it breaks unevenly. Its specific gravity is about 1·39. It consists of—

	Centesimally represented. Sir H. Davy.
Tannic acid,..........................	54·5
Extractive matter,......................	34·0
Mucilage,..............................	6·5
Insoluble matters,.....................	5·0
	100·0

Malabar cutch is in amorphous masses of a rusty color externally; but inside, of a dull, dark brown; gritty, and covered with leaves. Its specific gravity may be stated as 1·40. Its composition is—

	Centesimally represented.
Tannic acid,..........................	45·8
Extractive matter,......................	39·9
Mucilage,..............................	8·0
Impurities,.............................	6·3
	100·0

Good catechu is brittle, but compact and has a dull fracture It is inodorous, but possesses a very astringent taste. The whole of it, except earthy matters, which are probably communicated during the preparation, is soluble in water. The tannin and extractive are dissolved by alcohol. By heating the catechu with water, exposing it to a boiling heat for some time, and then evaporating to dryness, the extractive matter may be oxidized, and thus rendered insoluble in spirit.

The tannic acid in catechu, in its general characters, resembles, but, in particular reactions, differs from that of galls, as in being soluble in alcohol, and also in dissolving more readily in water. It gives a dirty green precipitate with sesquisalts of iron, but occasions no deposit in a solution of tartrate of antimony and potassa —tartar emetic. Gelatin is thrown down in a mass, which gradually becomes brown.

When pulverized catechu is infused in repeated portions of cold water—which remove the tannic acid—and an aqueous decoction of the residue is made by boiling, the latter, as it cools, deposits catechuic acid in an impure condition. After a thorough edulcoration, this is subjected to ebullition with animal charcoal in six times its weight of water, and the liquid having been filtered while hot, throws down the acid as before, but in a pure state. COOPER has described it as collecting upon leather tanned by catechu.

Catechuic acid is white, has a silky or micaceous appearance, and forms, when slowly deposited, groups of acicular crystals. It is slightly soluble in cold, but wholly so in about four parts of hot water. It is dissolved by six parts of cold, or three of boiling, alcohol; and by one hundred and twenty-eight of cold, or seventy-eight parts of hot, ether. When heated, it readily fuses, and on attaining the atmospheric temperature concretes into a brittle mass. If raised to rather above 400° Fahr., it is decomposed. From the analyses of SVANBERG, ZWINGER, and HAGEN, the formula of *anhydrous* catechuic acid—combined with oxide of lead—is $C_{14}\,H_6\,O_6$. A solution of catechuic acid in carbonate of potassa exposed to the air acquires a dark color, and changes, according to SVANBERG, into rubinic acid—$C_{18}\,H_6\,O_9$—and japonic acid—$C_{12}\,H_4\,O_4$. When submitted to dry distillation, catechuic acid affords a crystalline product, which may be purified by sublimation, and which ZWINGER has termed, pyrocatechuic acid, $C_6\,H_2\,O$.

A solution of catechu in water has a reddish-brown color, and gives the following results:—Acids cause the shade to be brightened; alkalies darken the menstruum; protosalts of iron give olive-brown precipitates; those produced by the sesquisalts have a greener hue; salts of tin yield brownish-yellow, and those of lead, brick-colored deposits; while the subsidence occasioned by acetate of copper, or bichromate of potassa, is brown.

Catechu is often adulterated with various other astringent principles, or by the incorporation of clay, sand, ochre, and similar bodies. When other extracts have been mixed with it, it has often a dark and almost black color, with a shining appearance, and occasionally feels glutinous or clammy. When of good quality it is entirely soluble, both in water and alcohol, the silicious, aluminous, and other sophistications may thus be readily detected.—*Normandy.*

The reactions of catechu are so varied, that it is now used for most compound colors, as black, brown, green, drab, and fawn; and its permanency renders it of high estimation.

It was first introduced to the trade for the dyeing of brown upon cotton, which is dyed by a very simple process. A little catechu is dissolved in boiling water, adding to it a small portion of nitrate or sulphate of copper; the cotton is wrought or steeped in this for an hour or two, and then taken out and wrought through a hot solution of bichromate of potash, which produces a brown of very great richness: it is washed from this, and then passed through a little soap and water, which softens the fibre.

CHICA, says URE, is a red coloring principle, used by some Indian tribes for staining the skin, and is extracted from the *Bignonia chica*, by boiling its leaves in water, decanting the decoction, and allowing it to cool, when a red matter falls down, which is formed into cakes and dried. This substance is not fusible, and when burned, diffuses an odor similar to that occasioned by the same treatment of animal matter. It is insoluble in cold water, but readily dissolves in alcohol and ether, from which it may be recovered, by evaporation, unchanged. It is soluble in carbonated and caustic alkaline lies, and is precipitated from them by the acids without alteration. An excess of alkali, however, speedily decomposes it. Nitric acid transforms it into oxalic acid and bitter matter, and chlorine makes it white.

The native Indian tribes boil the leaves of the chica, and then produce a separation of the fecula by adding pieces of the bark of a tree, common to that part of the world, called *aryana;* it is then washed and formed into round cakes, about two inches thick and five or six inches in diameter, which are dried and considered fit for use. In this state the chica dye is now occasionally met with in commerce; it gives to cotton and woollen an orange-yellow color.

NAPIER has also designated chica as *carajuru*, but the substance obtained from Para in Brazil, under that name, seems to possess some different properties. It is thus described by VIREY:—As a substance not only analogous in its physical and chemical characters to chica, but of a red-brown violet tint, much more beautiful and rich, and like vermillion, whilst the other appeared duller and much inferior, has been obtained from Brazil, it may be useful to give fresh details about this product, which has been imported to be tried in dyeing. The crajuru, carajuru, or, according to others, caracuru, is a kind of powder or fecula, in pieces somewhat light, inodorous, insipid, or slightly bitter, insoluble in water, but taken up by alcohol, ether, and the oils and fats without being completely resinous, burning with a flame, and leaving a quantity of grey ash. It is completely dissolved by alkalies; and acids, if they are not concentrated, precipitate it without greatly altering its color. The carajuru now brought into Europe must furnish a rather strong and beautiful dye, the brilliancy of which appears superior to that of Orleans.

COCHINEAL—*Cochenille*, French; *Koschenilje*, German; *Coccus*, Latin—is the name applied to a small insect that inhabits the nopal—*cactus coccinilifera*—

and three or four other species of cactus, from the juice of which it extracts its nourishment, and whence its entomological appellation, *coccus cacti*, is derived. The female, which is without wings, constitutes the commercial article.

The insect is a native of Mexico, and has, for an indefinite period, been employed by the inhabitants of that country for tinctorial purposes. When the Spaniards effected an entrance in 1518, it drew their attention, and CORTEZ was, subsequently, commanded by the court to obtain as large an amount of it as was practicable. The earlier Spanish writers described it as an insect; but, at a later period, it was regarded as the seed of a plant, and this opinion continued prevalent, notwithstanding much discussion on the subject, until about the year 1725. In 1668, a crude article on cochineal was published in the Philosophical Transactions, which clearly states that it belongs to the animal kingdom. Dr. LISTER, in 1672, conjectured that it was a sort of kermes. This opinion has been shown to be well-founded. LEEUWENHOECK made a microscopical examination of it in 1703, and ascertained it to be an insect. About 1757, a Mr. ELLIS obtained portions of the cactus plant, and observed that the specimens were full of the nests, in which it appeared in various states, from the most minute, when it traverses the plant, to the period when it becomes fixed, and reposes in a web of its own construction. Mr ELLIS found, by the assistance of the microscope, the true male insect, in the parcels which had been sent to him from America, and, in consequence of this discovery, Dr. GARDEN caught, in 1756, a male cochineal fly, which, he observes, is rarely to be met with. He supposes that there are from one hundred and fifty to two hundred females for each male. The insects increase rapidly in number. The females live about two months; the males half that time. The season of rearing and gathering lasts about seven months, during which period they are collected thrice. After each *crop*, some of the branches and leaves are preserved under shelter, and, on the return of the season, are distributed over the plantation. A few females are put into a small nest, made of some downy material, and the young insects quickly spread themselves out upon the leaves, to which they become attached. They are gathered by being brushed from the plant, with the plumous end of a quill, into boiling water, in which they are kept a few seconds. This not only instantaneously deprives them of life, but causes them to swell to twice the natural size. They are afterwards spread out, dried, and then packed for the market. Some cultivators use steam instead of hot water, while others place them in an oven, or upon a hot plate. The difference in the appearance of the cochineal is caused by these different modes of killing and heating the insects. They shrivel in drying, and assume the form of irregular grains, fluted and concave. The best sorts seem to be dusted with a white powder, and are of a slaty-grey color; but this aspect is often imparted by the application of powdered talc or carbonate of lead, to deceive the purchaser. A good lens, however, will readily distinguish these powders from the real wool which gives the silvery character.

Cochineal has been the subject of several chemical investigations. It was examined by JOHN in 1813; by PELLETIER and CAVENTOU in 1818; again by PELLETIER in 1832; still later by PREISSER; and in 1847 by WARREN DE LA RUE.

Dr. JOHN gives the following as the result of his analysis:—

	Centesimally.
Coloring principle—semi-solid, soluble in water and alcohol,	50·00
Gelatin,	10·50
Waxy fat,	10·00
Modified mucus,	14·00
Membrane,	14·00
Alkaline phosphates and chlorides, phosphates of lime, iron, and ammonia,	1·50
	100·00

In 1832, PELLETIER published the composition of the coloring matter of cochineal as prepared by himself and CAVENTOU. After the substance had been dried *in vacuo* at a gentle heat, to remove the last traces of alcohol and ether, it yielded, when burnt with oxide of copper—

	Centesimally.
Carbon,	49·33
Hydrogen,	6·66
Oxygen,	40·45
Nitrogen,	3·56
	100·00

It was stated by PELLETIER that he did not greatly rely on the correctness of these results.

PREISSER, by adding what he terms *hydrate of oxide of lead*—which, says DE LA RUE, is nothing but a basic nitrate, $2\,(3\,\mathrm{Pb\,O}, \mathrm{NO_5}) + 3\,\mathrm{HO}$—to an aqueous decoction of cochineal, the fat of which had been previously removed by ether, suspending the lead compound in water, and decomposing it by a stream of sulphide of hydrogen, obtained needles of a pale yellow color, which became perfectly white by washing with ether and pressing between bibulous paper. These crystals, which, according to PREISSER'S assertion, are soluble in water and alcohol, but less so in ether, assume, in contact with the atmosphere, the purple-red of the tinctorial matter of cochineal. He also asserts that the colorless modification gives a white precipitate on adding acetate of lead to its aqueous solution, and that this assumes a purple hue on being exposed to the air. It was proposed by him that the term *carmin*, hitherto applied to the red coloring matter, should be given to the white crystals, and that the red substance should be designated *carméin*.

M. A. E. ARPPE repeated the experiments of PREISSER without obtaining similar results, and concluded that the coloring matter had not been obtained in a state of purity.

PELLETIER procured carméin—coccinellin, red carmin—as follows:—The pulverized cochineal was first deprived of fat by means of ether; it was then boiled in alcohol, having a specific gravity of 0·820, as long as it continued to yield color; the greater part of the alcohol was then distilled off, and the solution allowed to evaporate spontaneously, when a compound of carméin, fat, and animal matter remained, which, treated with cold alcohol, left a brown extract-like residue. The carméin was precipitated from the alcoholic solution, by mixing it with a similar bulk of ether. It possesses, according to the same authority, the following properties:—It is of a deep purple-red color, permanent in the air, and soluble in water, to which it communicates a very intense purple hue; alcohol also dissolves it, but with difficulty. It is insoluble in ether, and in fat and volatile oils. Its composition may be represented as $C_{32}\ H_{26}\ O_{20}\ N$. Chlorine, iodine, and bromine destroy its color: the dilute acids impart to it a yellow tint, which reverts to purple on neutralizing the solution with an alkali. When dissolved in water, acids do not throw it down, but bitartrate and binoxalate of potassa render it scarlet. The alkalies cause it to become violet, and when its alkaline solution is exposed to the atmosphere, oxygen is gradually absorbed, and the coloring matter is decomposed. Hydrate of alumina causes the rapid formation of a pink lake, which, on being subjected to ebullition, acquires a violet tinge. Alum communicates a purple hue, but occasions no precipitate; acetate of lead gives a violet, chloride of tin a dark red, the salts of iron a brown, and those of copper a violet subsidence. The subsalts of mercury throw down a violet, and the protonitrate causes a scarlet precipitate. A solution of carméin is little affected by nitrate of silver.

The carméin or coccinellin of PELLETIER and CAVENTOU was rendered impure, according to DE LA RUE, by phosphoric acid, and by the presence of nitrogenous matter. The pure coloring principle of cochineal is termed, by the latter authority, *carminic acid;* from the properties—which he found it to possess—of uniting with bases, and being capable of abstracting some of them from their combinations with acetic acid.

Carminic acid may be prepared by precipitating an aqueous decoction of cochineal by oxide of lead, washing the subsidiary compound, and decomposing it by sulphide of hydrogen. The same procedure is repeated with the red filtrate so obtained. The colored menstruum procured from this second operation, is now evaporated to dryness *in vacuo* over sulphuric acid; the residue dissolved in absolute alcohol in a state of ebullition; the spiritous solution is digested with a portion of dry *carminate of lead* to remove all traces of phosphoric acid, and then concentrated; next it is diluted with an equal bulk of ether, which throws down the nitrogenous impurity in red flocculi, which contain some of the coloring matter: the liquid is finally filtered, and when it is evaporated, pure carminic acid remains.

When thus prepared, it is in the form of a purple-brown friable mass, transparent when viewed through a microscope; easily pulverizing to a fine red powder; soluble to any extent in water and spirit, but only slightly so in ether, which, however, does not throw it down from its alcoholic solution when it is free from nitrogenous matter. Hydrochloric and sulphuric acids, although in a concentrated state, dissolve without destroying it; nitric acid, even when very dilute, as also chlorine, iodine, and bromine, decompose it; the fixed alkalies and ammonia merely change the color of its aqueous solution to purple, but in the alcoholic tincture they produce purple precipitates; each of the alkaline earths causes a subsidence of a similar hue; sulphate of alumina gives no deposit, but on adding a drop of ammonia, the carminic acid is taken down as a beautiful crimson lake; acetates of lead, copper, zinc, and silver occasion purple precipitates, the latter of which is immediately decomposed, and metal separated; the nitrates of lead, mercury, and silver, furnish reddish deposits; proto- and bi-chloride of tin merely change the color to a deep crimson.

Carminic acid is composed of—

		Centesimally represented	
		Theory.	De la Rue.
28 Eqs. Carbon,..	168	54·19	54·13
14 Eqs. Hydrogen,..........	14	4·52	4·62
16 Eqs. Oxygen,....	128	41·29	41·25
1 Eq. Carminic acid,......	310	100·00	100·00

It may be heated to 276° Fahr. without decomposition; on gradually increasing the temperature, a quantity of an acid liquor is produced, and at a red heat it intumesces and gives off a small quantity of ruddy fumes, which condense: there is no oily matter.

On boiling carminic acid with nitric acid, having a specific gravity of 1·4, oxalic and a new acid, termed by DE LA RUE nitrococcusic acid, are produced. The former is removed by the nitrate of lead, when the latter may be crystallized from the filtrate in rhombic plates of a yellow color, containing two equivalents of water of crystallization. It is bibasic, and all its salts are more soluble in water than the acid itself. It deflagrates when heated, as do also its salts, that of silver being very explosive. It is soluble in ether, alcohol, and water, and stains the cuticle yellow.

A number of analyses made by DE LA RUE, as well of the acid itself, as of its compounds, confirmed the adoption of the formula $C_{16}\ H_5\ O_{18}\ N_3$:—

		Centesimally represented.	
	At. weight.	Theory.	Experiment.
16 Eqs. Carbon,............	96	33·45	33·75
5 Eqs. Hydrogen,..........	5	1·74	1·91
18 Eqs. Oxygen, ...	144	50·18	49·37
3 Eqs. Nitrogen,............	42	14·63	14·97
1 Eq. Hydrated nitrococcusic acid,......	287	100·00	100·00

The equivalent of the anhydrous acid as it exists in combination with bases is 269, and its composition is—

	At. weight.	Centesimally
16 Eqs. Carbon,......................	96	35·69
3 Eqs. Hydrogen,......................	3	1·12
16 Eqs. Oxygen,......................	128	47·58
3 Eqs. Nitrogen,......................	42	15·61
1 Eq. Anhydrous nitrococcusic acid,	269	100·00

The *crystallized* acid, obtained by evaporating its aqueous solution, is represented by the formula $HO, C_{16}\ H_3\ O_{16}\ N_3, + 2\ HO$.

The formula of such of the salts as have been analysed are annexed:—

Nitrococcusate of ammonia, $2\ NH_4O,\ C_{16}H_3O_{16}N_3 + HO$.
" baryta, $2\ BaO,\ C_{16}H_3O_{16}N_3 + 2\ HO$.
" potassa, $2\ KO,\ C_{16}\ H_3\ O_{16}\ N_3$.
" silver, $2\ AgO,\ C_{16}\ H_3\ O_{16}\ N_3$.

DE LA RUE says, further, with regard to nitrococcusic acid, that it may be represented by—

$$2\ HO,\ C_{16}\left\{\begin{matrix} H_3 \\ NO_4 \end{matrix}\right\}O_4,$$

and concludes that it is isomeric with the trinitroanisic acid of CAHOURS.

DE LA RUE obtained from the mother-liquor of carminic acid, a large quantity of a nitrogenous body, which could only be dried to a soft uncrystalline solid; he also procured from the same source a crystalline compound, closely resembling, both physically and chemically, that obtained by LIEBIG from casein, and by him termed *tyrosin*. One thousand parts of cochineal yielded about four of the new body. It is soluble both in alkalies and acids, and appears to be of the neutral class; it crystallizes in fine silky needles, slightly soluble in cold, but far more so in hot water; and insoluble in alcohol and ether. It has hitherto been represented by the formula $C_{18} H_{11} O_6 N$.

The pigment known as *carmin* is generally prepared by subjecting cochineal to ebullition with carbonate of potassa or soda, and throwing down the coloring matter by a weak acid, or an acid salt; sometimes binoxalate of potassa, at other times a mixture of bitartrate of potassa with alum is employed; occasionally the precipitation is accelerated by the addition of gelatin or albumen.

A German process is to boil one pound of powdered cochineal in a gallon of water for a quarter of an hour, then adding one ounce of pulverised alum, and continuing the ebullition for three minutes longer; after this the vessel is removed from the fire, allowed to stand for some time undisturbed, and the clear supernatant liquid decanted into clean receptacles, which are set aside for several days, when about one and a half ounce of carmin is deposited. An additional half ounce of rather inferior quality is obtained by permitting the mother-liquor again to repose for a length of time.

The French make a decoction of cochineal by boiling one pound of it in three gallons of water for fifteen minutes; one ounce of powdered bitartrate of potassa is added, and after ten minutes' seething, half an ounce of alum. Ebullition is further continued for two minutes, and when, after the removal of the vessel from the fire, subsidence has occurred, the clear menstruum is set aside in clean glass pans, in which the carmin deposits. This is afterwards drained, and dried in the shade.

Madame CENETTE'S process, which has acquired some celebrity, is the following:—Mix two pounds of powdered cochineal, of the best quality, with fifteen gallons of boiling distilled water, and after two hours' ebullition, add three ounces of pure nitrate of potassa, and, in three minutes, four ounces of binoxalate of potassa. Boil for ten minutes longer, remove from the fire, allow to settle for four hours, carefully decant the clear liquor into shallow bell glasses, and set aside for three weeks. At the end of this time, the film of mould formed on the surface is dexterously removed, without disturbing the liquid portion, which is then drawn off by means of a pipette. The precipitated carmin left at the bottom of the vessels, when drained and dried in the shade, is of superior brilliancy and beauty.

Good carmin has not yet been manufactured in this country, although many attempts have been made to do so. The cause of failure, if one may judge from the following anecdote related by Sir H. DAVY, is the absence of a certain actinic influence in the sun's rays in the more Northern climate of Britain:—

A maker of carmin, who was aware of the superiority of the French article, went to Lyons for the purpose of improving his process, and bargained with the most celebrated manufacturer in that city, for the acquisition of his secret, for which he was to pay £1000. He was shown all the various manipulation, and the most beautiful color produced, but he found not the least difference in the French mode of fabrication, and that which had been constantly adopted by himself: he appealed to his instructor, and insisted that he must have kept something concealed. The man assured him he had not, and invited him to inspect the process a second time: he minutely examined the water and the materials, which were, in every respect, similar to his own, and then, very much surprised, he found that his labor and money were lost, for the air of England acted prejudicially on the carmin. Stay, said the Frenchman, do not deceive yourself; what kind of weather is it now? A bright sunny day, replied the Englishman. And such are the days, said the Frenchman, in which good color is made. Were one to attempt to manufacture it on a dark and cloudy day, the results would be the same as yours. The French advice, then, is only to make carmin on bright sunny days.

Carmin is often adulterated with starch, alumina, or vermillion; oftentimes, also, a portion of the animal matter of the cochineal is accidentally mixed with it. These impurities are readily detected by heating the carmin with ammonia, which dissolves the coloring matter, and leaves the sophisticating body in an insoluble state.

It is perfectly impossible to judge positively of the quality of cochineal by its physical characters. In order to ascertain its value, recourse must be had to comparative experiments. ROBIQUET and ANTHOU have given two methods of determining the quality of cochineal, according to the quantity of carmin it contains. The process of the former consists in decolorizing equal volumes of decoctions of different samples of cochineal by chlorine, the same weight of each kind being taken. By using a graduated tube, the quality is judged of by the amount of chlorine employed for bleaching the menstruum. The method of M. ANTHOU is founded on the property which the hydrate of alumina possesses of precipitating the carmin from the solution, so as to decolorize it entirely.

The first process, which may be very good in the hands of a skilful chemist, does not appear to be a trustworthy method for the consumer; it being, in the first place, difficult to procure perfectly identical solutions; and in the next place, it is impossible to keep them a long time without alteration, as chlorine, when dissolved in water, reacts, even in diffused light, on this liquid, decomposes it, appropriates its elements, and gives rise to compounds which possess an action quite different from that of the chlorine solution in its primitive state.

The second mode of operation seems to be preferable, as the proof liquor may be kept a long while without change. A graduated tube is also used, each division representing one-hundredth of the coloring principle. Thus, the quantity of liquor added exactly represents the amount in hundredths of tinctorial matter contained in the decoction which has been submitted to examination.

Dr. PENNY has suggested a very simple process for ascertaining the comparative tinctorial powers of different specimens of cochineal. The method is based upon the bleaching action of ferricyanide of potassium in presence of a free alkali. Twenty grains of the cochineal finely pulverised are dissolved with a gentle heat, in two ounces of weak *aqua potassæ;* the menstruum is afterwards diluted with four ounces of water, and allowed to cool. A burette is then made up in the usual way, with water and five grains of the above-named test salt; and the solution added slowly to the cochineal liquid, until the purple color of the latter is discharged, and changed to a dull reddish-brown tinge. The precise moment when this result is produced, may be easily ascertained by spotting the liquid occasionally on a white slab. A comparative trial with cochineal of first quality will show at once the relative economic value of the sample under examination. This method also serves for testing lac dye.

Scarlet is communicated to wool and silk by dyeing first in a solution of annotta, and after by means of a mixture of a decoction of cochineal with cream of tartar and dyers' spirit, which is a mixture of protochloride and bichloride of tin; crimson is given by a decoction of cochineal with alum and chloride of tin without annotta.

FRENCH BERRIES.—*Grains d'Avignon*, French; *Gelbbeeren*, German.—The berries of the different species of *Rhamnus;* known also as Spanish and Turkey, but more especially as Persian, berries. They have been chemically examined by CHEVREUL, HENRY, KANE, and PREISSER. They are of two qualities: one of these comprises olive-green and larger berries than those of the other variety, which are brown and wrinkled, and appear to have remained longer on the trees. The coloring matter of the two kinds is, according to KANE, quite distinct.

In this, as in other cases, PREISSER asserts that the tinctorial principle may be brought to a colorless state by reducing agents; and when in this form he has termed it *rhamnin.*

It may be procured from an ethereal tincture of the berries, which, after being reduced by distillation to about one-third its original bulk, is mixed with water and a small quantity of hydrated oxide of lead; it is then filtered, and the entire coloring matter abstracted from the clear yellow liquor, by a further addition of the metallic oxide; this lead compound is next decomposed by sulphide of hydrogen, the clear filtrate evaporated to dryness, and the residue washed with ether.

Rhamnin is an almost colorless crystalline powder, of a bitter taste, and soluble in water, alcohol, and ether. Its solutions on exposure rapidly acquire a yellow hue, the rhamnin passing into *rhamnèin.* Nitric and chromic acids, bichromate of potassa, and other oxidizing agents, immediately produce the same change, and under the influence of alkalies the liquors acquire a dark-brown color.

Rhamnèin—*chrysorhamnin*—was obtained from the green berries by means of ether; it has a golden yellow color, and is crystallizable; it is almost insoluble in cold water, but dissolves in alcohol and ether. After desiccation at 212°, its formula, according to KANE, is $C_{23}\,H_{11}\,O_{11}$. When its alcoholic solution is decomposed by acetate of lead, a fine yellow precipitate falls, the composition of which, after having been dried at 212°, is represented by $2\,PbO,\ C_{23}\,H_{11}\,O_{11}$.

When rhamnèin is boiled in water, and in contact with air, it passes into *xanthorhamnin*—$C_{23}\,H_{12}\,O_{14}$.

1 Eq.	Rhamnèin, chrysorhamnin, ..	$C_{23}\,H_{11}\,O_{11}$
1 Eq.	Water, ...	$H\ \ O$
2 Eqs.	Oxygen, ...	O_2
1 Eq.	Xanthorhamnin, ...	$C_{23}\,H_{12}\,O_{14}$

Xanthorhamnin is contained in the brown shrivelled Persian berries, from which it may be procured by digesting them in hot water; it is insoluble in ether, but dissolves freely in water and in alcohol, and remains, on evaporating the infusion or tincture, in the form of an extract. KANE found its compound with oxide of lead to be $2\,PbO,\ C_{23}\,H_{12}\,O_{14} + 3\,HO$.

FUSTET—*Fustet*, French—is the name given to the wood of the *Rhus cotinus*, a shrub cultivated in Italy and Southern France, for the double purpose of a dyeing and tanning material. After being cut down it is deprived of its bark, and broken into small pieces, in which state it is met with in commerce. It is also termed *young fustic—bois de fustet*—in contradistinction to the wood of *morus tinctoria*, which is also denominated fustic—and has been known as *Venetian sumac.* It has long been used in France for giving a yellow dye. In the south of that empire the leaves of *Rhus myrtifolia* are also employed for tinctorial purposes, under the appellation of *redoul*, or *rodou.* Fustet affords a yellow crystalline coloring matter, which PREISSER has separated thus:—The tannic acid was first precipitated from the decoction by means of gelatin; on filtering, a greenish-yellow liquor was obtained, which was evaporated to dryness, and the residue treated with ether. This solution was distilled in a retort, and water, together with hydrated oxide of lead, added to the residue, causing the formation of a yellow compound, which was decomposed by sulphide of hydrogen; the liquor yielded small yellow crystals of *fustin*, which were purified by edulcoration with ether.

Fustin is slightly bitter; it dissolves in water, alcohol, and in ether, and acquires color on exposure to the atmosphere. Sulphuric and nitric acids communicate a yellow tinge to its solutions. Tin salts cause an orange-yellow, and those of iron an olive-green precipitate. Acetate of lead causes a subsidence at first white, but on exposure becoming yellow. The alkalies immediately redden the solution Fustin appears to resemble rhamnin, and has a great tendency to absorb oxygen from the air; this latter property affects its use as a dye. The colors being fugitive, it is seldom employed alone, but as an assistant to strike some particular tint. It is not used in the dyeing of cotton goods.

FUSTIC.—*Bois-jaune*, French; *Gellsholz*, German.

—The wood of the *morus tinctoria.* This dye-stuff has been long known. It is uncertain when it was introduced, but mention is made of it in a book published in 1692. The tree grows spontaneously in Brazil and the West Indian islands, and attains a great altitude. The wood is of a sulphur color, with veins of an orange hue.

Fustic, or, as it has been termed, *yellow wood*, has been severally examined by Georges, Chevreul, and Preisser. The results of the first of these have long been regarded as unsatisfactory. Chevreul says that two coloring principles exist in the yellow wood capable of dyeing alumed stuffs yellow, and has called them *yellow* and *white morin.* Both sublime in crystals. They are distinguished by the aqueous solution of the yellow morin becoming green with sesquisulphate of iron, whilst that of the white turns chestnut red.

The white morin is found principally in the crystalline powder which exists in the heart of the tree. The yellow morin, or, as Preisser termed it, *moréin*, is procured by exhausting the wood with water, evaporating the extract until it deposits crystals on cooling, dissolving these in ether, and allowing them to re-form. These two principles are easily altered by the air, by exposure to which they acquire a reddish tint.

The experiments of the last-named chemist led to the conclusion that the white and yellow morin were only modifications of one and the same body, and on adopting the same process of extraction as for other coloring matters, he obtained *morin*—or white morin—which, in contact with the atmosphere, absorbs oxygen, assumes a yellow color, and is converted into moréin.

Morin is dissolved by mineral acids, which communicate to it a yellow color. Sesquisulphate of iron tinges it garnet-red. Acetate of lead gives a white precipitate. Alkalies cause it to take a beautiful dark yellow, approaching to orange. It absorbs oxygen on being boiled in water, and is changed into moréin, which deposits on cooling. The same result is attained more speedily by oxidising morin by chromic acid or bichromate of potassa. Both furnish moréin and oxide of chromium.

Moréin crystallizes in beautiful yellow laminæ. It is volatile; perceptibly acid to litmus paper; not very soluble in cold, but more so in boiling water; it is readily taken up by alcohol or ether; acids dissolve it and darken the color; nitric acid tinges it brownish-red, and causes the evolution of ruddy fumes; alkalies change its hue to orange; acetate of lead causes a golden-yellow, and sesquisulphate of iron a dark-green precipitate.

Moréin is not very permanent. After a time it appropriates a further quantity of oxygen, and becomes reddish-brown. This absorption is perceptible when the solution is brought into contact with oxygen over mercury. This is the cause of the red and brown principles which always occur in decoctions of fustic, and which exist at the surface of the wood, when it has been exposed to the action of air and light for any length of time.—*Preisser.*

Fustic has long been partially superseded for the dyeing of yellows upon cotton by quercitron bark, and both are now almost totally displaced by bichromate of potassa and lead. Fustic is, however, sometimes used in giving a green color to cotton yarn. The goods are first dyed blue, and are then passed through crude acetate of alumina; they are next subjected to the action of a hot decoction of fustic, which communicates a rich shade of green. The same color is also often imparted to light cotton tissues, as gauzes and muslins, by similar means. It is still much used for greens on silk and woollen; it is also employed with other woods for compound hues, as drabs, fawns, olives, *et cetera*, and is used with logwood for dyeing black, as well on cotton, as on silk and woollen fabrics.

Galls—*Noix de Galle*, French; *Galläpfel*, German; *Gallæ*, Latin—are excrescences which form upon the branches and shoots of *Quercus infectoria*, being caused by the puncture of the female of the *Cynips gallæ tinctoria*, or gall-wasp, which deposits its egg in the perforation, occasioning the development of the nut, within which the larva is perfected, and whence it finally eats its way out. Those of the best quality are known in commerce as black or blue galls, and are collected before the insect has escaped; the white galls are those from which it has departed, and are, consequently, perforated with a small circular hole. They are of a brownish or dingy-yellow color, and are larger than the others, but are not so heavy or astringent. Gall-nuts are chiefly imported from Turkey; they were used in medicine in the time of Hippocrates, and have also been very long known as sources of black dye, and employed in the manufacture of writing inks. The first attempt at an analysis of them was made about the middle of last century by Dr. Lewis, who detected in them a substance which, said he, *coagulates with isinglass and blackens solutions of iron.* Deyeux regarded their active principle as a resin. Seguin was probably the first who accurately determined the nature of its action upon solutions of gelatin, and upon the skins of animals, and who applied the generic term *tannin* to this principle, as existing in a variety of substances employed in the conversion of hides into leather.

From an aqueous decoction of five hundred parts of galls, Sir Humphrey Davy obtained one hundred and eighty-five parts of solid extract, which he found to consist of—

Tannin,	130
Gallic acid,	31
Mucilage,	12
Inorganic matter,	12
	185

From the analyses of Guibourt, the following constituents were found to pre-exist in them:—

	Centesimally represented.
Tannic acid,	65·0
Gallic acid,	2·0
Ellagic and luteo-gallic acids,	2·0
Brown extractive substance,	2·5
Gum,	2·5
Starch,	2·0
Sugar,	1·3
Clorophyl and volatile oil,	0·7
Woody fibre,	10·5
Water,	11·5
Albumen and salts,	—
	100·0

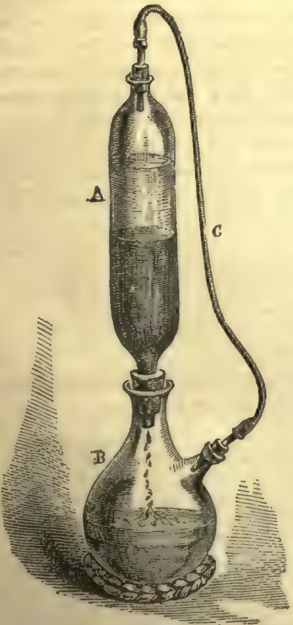
An infusion of galls occasions precipitates in most metallic solutions, the characters and colors of which are sometimes accepted as indications of the oxide present. In the following table, abridged from Brande, the solution of the metallic salt employed is shown in the first column, and the third and fourth give the color of the precipitate; the first of the two latter columns being the results obtained by Brande, the latter those of Dumas. It may be observed, says the former authority, that discrepancies arise in this case from the strength of the metallic solution, and also from its acid or basic character, so that neutral menstrua should as far as possible be used.

Solution of metallic salt.	Color of precipitate.	
	Brande.	Dumas.
Protochloride of manganese,....	Dirty-yellow.	—
Protosulphate of iron,.........	Purple tint.	—
Sesquisulphate of iron,.........	Black.	Blue-black.
Chloride of zinc,...............	Dirty-yellow.	—
Acid protochloride of tin,.......	Straw color.	Yellowish.
Acid bichloride of tin,..........	Fawn color.	Fawn color.
Protochloride of copper,........	Yellow-brown.	?
Nitrate of copper,.............	Green.	Grey.
Nitrate of lead,...............	Dingy-yellow.	White.
Tartrate of antimony and potassa,	Straw color.	White.
Chloride of cobalt,.............	—	Yellow-white.

Tannin or tannic acid, the chief constituent of galls, was not obtained in a pure state until 1834, when a method of separating it was pointed out by Pelouze, which enabled him to examine its properties, and ascertain its composition.

The process is as follows:—A glass vessel similar to that represented by A—Fig. 349—is fitted into a two-necked flask, B; the upper recipient is about half filled with powdered galls, a small plug of cotton wool being placed at its lower conical end to prevent any of the powder passing through; washed ether—that is, ether containing about a tenth part of water—is then poured upon the galls, till, when they have absorbed as much as possible, the vessel is nearly full. The perforated corks, with the elastic tubing, C, are then replaced, and percolation allowed to proceed. The liquid, as it flows into B, divides into two strata, the lower of which is a concentrated aqueous solution of tannic acid, the upper being ether containing a little tannic and gallic acid. These menstrua are separated, and the lower, having been agitated or washed with *pure* ether, is evaporated, *in vacuo*, over sulphuric acid; aqueous and ethereous vapors pass off, and the pure tannin is obtained as a bulky pale-yellow residue. According to Pelouze, the tannin of galls is more soluble in water than the other constituents, so that it abstracts the water from the ether, and forms with it the lower stratum of liquid, upon which the ether itself floats. When the powder of gall-nuts is treated with pure anhydrous ether, a magma is formed, and no fluid separates, but, according to Guibourt, a little alcohol in the ether facilitates the process. The method above described, however, answers well, and although other processes have been suggested by Berzelius, Cadet, and others, that of Pelouze appears, upon the whole, to be the simplest and most effectual.

Fig. 349.



Pure tannic acid is nearly colorless, inodorous, pre-eminently astringent in taste, uncrystallizable, very soluble in water, and less so in pure alcohol and ether. Its aqueous solution reddens litmus, and decomposes the alkaline carbonates with effervescence. It combines energetically with gelatin, and when a piece of skin or bladder is immersed in its aqueous solution, the tannic acid is entirely abstracted; whereas, any gallic acid that may be present, remains dissolved. It also furnishes an abundant white precipitate in menstrua containing isinglass or glue. A concentrated aqueous solution of tannic acid is thrown down by hydrochloric, nitric, sulphuric, phosphoric, and arsenic acids; but not by oxalic, tartaric, lactic, acetic, or citric acid. By the prolonged action of acids and alkalies, it undergoes various and often complicated changes, amongst which, its conversion into gallic acid is most common.

Tannic acid has been analysed with the following results:—

	At. weight.	Centesimally represented. Theory.	Berzelius.	Liebig.	Pelouze.
18 Eqs. Carbon,....	108	50·94	52·69	52·51	51·77
8 Eqs. Hydrogen,..	8	3·77	3·86	4·12	3·98
12 Eqs. Oxygen,.....	96	45·29	43·45	43·37	44·25
1 Eq. Tannic acid,	212	100·00	100·00	100·00	100·00

According to Berzelius and Pelouze, tannic acid is anhydrous, and tannate of lead, when dried at 120°, is represented by them as $PbO, C_{18} H_8 O_{12}$. Liebig, by adding tannic acid to an excess of a hot solution of acetate of lead, obtained a salt which he considers to be $3PbO, C_{18} H_5 O_9$; he consequently regards the tannic acid as *tribasic*, and represents it, when isolated, by the formula $3HO, C_{18} H_5 O_9$. Löwig regards it as monohydrated, and gives to it the formula $HO, C_{18} H_7 O_{11}$, which, he observes, is consistent with all its salts except Liebig's tannate of lead.

An aqueous solution of tannic acid out of contact with air, sustains no alteration; but, if exposed to the atmosphere, it gradually loses its limpidity, and a slightly greyish crystalline matter, consisting almost entirely of gallic acid, subsides. This change is facilitated by diluting the menstruum. For procuring gallic acid in a perfectly pure state, it is merely necessary to treat the above solution, after its mutation, with animal charcoal, and to filter it in a state of ebullition, through paper previously washed with dilute hydrochloric acid. The acid falls down in crystals as the liquid cools. If a solution of tannic acid be exposed to the action of oxygen in a glass jar over mercury, the gas will be absorbed, a corresponding volume of carbonic acid will be evolved, and in the course of a few weeks the liquor will appear as if traversed with numerous crystalline colorless needles of gallic acid.

Gallic acid may also be obtained by mixing powdered galls with water, and exposing the paste for some weeks to the air, at a temperature of 70° to 75°, occasionally adding water to prevent desiccation; the powder swells and becomes mouldy, and when the magma is subjected to pressure, a quantity of colored liquid may be squeezed out; the residue is then boiled in water, and the solution filtered while hot; on cooling, it deposits crystals of gallic acid, which may be purified by redissolving, and boiling with a little animal charcoal; the filtered solution then deposits the gallic acid in the form of white silky needles. Or, by another method, a concentrated cold infusion of gall-nuts is precipitated by sulphuric acid; the subsidence is first washed with very dilute sulphuric acid, pressed out, and then dissolved in the same menstruum—consisting of one part of acid to two of water—and boiled for some minutes; on cooling, it deposits crystals which are to be purified by a second crystallization, dissolved in hot water, and thrown down by acetate of lead; the resulting gallate of lead is then well washed, diffused in boiling water, and decomposed by a current of sulphide of hydrogen; colorless crystals of gallic acid are deposited as the filtered liquor cools.

E. N. KENT, in 1844, published a mode of preparing gallic acid from black ink. For this purpose, a portion of ink is well agitated with an equal quantity of pure sulphuric ether; the mixture is left at rest for a few minutes, and the ether having then separated, is decanted, and distilled nearly to dryness; the residue crystallizes on cooling. The ether may be returned to the ink, and the process repeated. The gallic acid may be purified by repeated crystallizations, or by precipitating its solution with acetate of lead, decomposing the resulting compound by sulphide of hydrogen, and crystallizing.

The remainder of the ether may be distilled off from the ink, which is left as good for *ordinary* purposes as before.

Most of the inks tried by the author of this method, gave the same result when treated with ether. Some, however, which had been prepared by boiling the galls, and exposure for a few days only, yielded principally tannic acid, and it is therefore advisable to test the ink with gelatin before attempting to thus prepare gallic acid.

Gallic acid crystallizes in long silky needles, of a slightly sour and astringent taste, soluble in about one hundred parts of cold, and in three of boiling water; it is readily soluble in alcohol, and sparingly so in ether: it occasions no precipitate with gelatin. The composition of the crystals is variously represented; the formula is probably $HO, C_7 H_3 O_5$. The acid dried at 212° Fahr. consists of—

		Centesimally represented.			
	At. weight.	Theory.	Pelouze.	Liebig.	Stenhouse.
7 Eqs. Carbon, ...	42 ..	49·41 ..	50·10 ..	49·85 ..	49·49
3 Eqs. Hydrogen, ..	3 ..	3·53 ..	3·64 ..	3·48 ..	3·53
5 Eqs. Oxygen, ...	40 ..	47·06 ..	46·26 ..	46·67 ..	46·98
1 Eq. Gallic acid, dried at 212°	85	100·00	100·00	100·00	100·00

But it is probable that the acid dried at 212° still retains an atom of water, being $2HO, C_7 H O_3$.

Basic salts of gallic acid, when exposed to the atmosphere, absorb oxygen, acquiring various shades of yellow and brown, till they ultimately blacken, in consequence of the formation of melanotannic acid—$2HO, C_{14} H_4 O_7$.

According to ROBIQUET, gall-nuts contain, besides tannin and the several principles which have already been pointed out by chemists, pectose and pectase. The latter, which exists both in the soluble and the insoluble state, acts synchronously upon the pectose and upon the tannic acid, converting the first into pectin, and the second into gallic acid. The presence of water and a temperature of 77° to 86° are requisite for this reaction, which resembles in every respect the ordinary phenomena of fermentation.

Ordinary tannic acid, which has been prepared with ether, contains sufficient pectase to pass spontaneously in the presence of water into gallic acid; but if care has been taken to purify it, or if its solution has been simply boiled for a few minutes, the change no longer occurs.

Synaptase, yeast, vegetal albumen, and legumin, have a very doubtful action upon tannin, and retard rather than accelerate its conversion into gallic acid.

In addition to gallic acid, formed on the exposure of moistened galls to the atmosphere, another principle, which seems to have been first observed by CHEVREUL, and denominated by BRACONNOT *ellagic acid*—a term derived from the word *galle* read backwards—is produced. It is insoluble in boiling water, and therefore remains after the gallic acid has been extracted. It may be dissolved out of the residue by very weak *aqua potassæ*, from which it is precipitated by hydrochloric acid as a tawny powder, tasteless, and almost insoluble in water, alcohol, and ether. According to PELOUZE, ellagic acid dried in the air may be represented by the formula $HO, C_7 H_2 O_4$. It is rendered anhydrous by drying at 250°, and then consists of—

		Centesimally.	
	At. weight.	Theory.	Pelouze.
7 Eqs. Carbon, ...	42	55·3	55·69
2 Eqs. Hydrogen, ...	2	2·6	2·48
4 Eqs. Oxygen, ...	32	42·1	41·83
1 Eq. Anhydrous ellagic acid,	76	100·0	100·00

It faintly reddens litmus. WÖHLER, in remarking upon its existence in the intestinal concretions known as *oriental bezoars*, gives its formula as $HO, C_{14} H_2 O_7$, and says there is no doubt of the latter being more correct.

Pyrogallic acid was first obtained by SCHEELE, by subliming galls; he considered it to be identical with gallic acid. It has subsequently been investigated by DEYEUX, by BRACONNOT, by PELOUZE, and, more recently, by Dr. STENHOUSE. It may be procured by drying gallic acid at 212°, and then heating it in a small glass retort, immersed in an oil-bath, to a temperature of 410° to 420°. Sublimation occurs, and it is deposited in white brilliant lamellar crystals. When thus obtained, it is very liable to be contaminated with empyreumatic oil, and can only be purified by repeated distillations, in each of which much acid is unavoidably lost, and the process thus rendered extremely troublesome and unproductive. The process recommended by STENHOUSE is as follows:—

Finely pounded gall-nuts are treated with successive portions of cold water, till they are exhausted. These extracts are then evaporated and strongly dried, till all the hygrometric water is driven off, and in this state they form a spongy deliquescent mass, in state and color very much resembling catechu. Instead of distilling this in a retort, it is much better to employ Dr. MOHR'S apparatus for subliming benzoic acid. This consists of a cast-iron pan, from three to four inches deep, and from eighteen inches to two feet wide. The dried extract is coarsely powdered, and spread equally over its bottom to the depth of about half an inch; the top of the pan is then covered with a diaphragm of bibulous paper—if this be pierced with a few small pin holes, the sublimation will be greatly facilitated—fitted closely over it by being pasted round its rim. The pan is surmounted with a paper cap twelve or eighteen inches high, well adapted to its top, and fastened by means of a cord passed two or three times round it. The apparatus is to be cautiously heated for ten or twelve hours on a sand, or still better, on a metallic bath, keeping the temperature as nearly as possible at 400°, though towards the end of the process it may be raised a few degrees higher.

The crystals of pyrogallic acid pass through the bibulous paper, which absorbs the empyreumatic oil by which they are always accompanied. Should the heat have been carefully regulated, the crystals, which are either large scales or needles, are perfectly white; if they are at all colored, which frequently happens, they may be easily purified by a second sublimation. This method possesses the great advantage, that a pound or more of the extract can be operated on at once; the apparatus is extremely cheap, and as it is not liable to break, it may be used for any number of times. On one trial, one thousand three hundred and eighty grains of dried extract yielded sixty-nine grains of perfectly pure crystals, and seventy-four grains which were slightly colored, in all one hundred and forty-three grains, or 10·3 per cent. As galls yield rather more than half of their weight of soluble matter, the quantity of pyrogallic acid obtainable from them by this process is very considerable. Dr. STENHOUSE mentions, however, that on a previous trial, when the sublimation was not so carefully conducted, he did not obtain more than half this quantity.

Pyrogallic acid is white, crystalline, and inodorous, but has a very bitter taste, resembling that of salicin. When pure, it does not change blue litmus paper; but if it has been sublimed at too high a temperature, it is accompanied with a little of some volatile acid, which causes it to redden litmus slightly. It gives a deep blue indigo color, but no precipitate, with solutions of protosulphate of iron; should sesquioxide be present, this hue soon changes to dark green, but if the salt is pure, the deep-blue remains for a considerable time. With sesquisulphate of iron it gives a yellowish, and with sesquichloride a much brighter red, but in neither case is there any deposit. When dropped into milk of lime, a reddish-purple color appears, speedily changing to brown. Caustic baryta occasions a dark-brown hue, readily becoming black. Dilute sulphuric acid first reddens, and then blackens it. Iodine leaves it intact. Chlorine immediately changes the color of the crystals to red, which, however, soon turns black.

Pyrogallic acid reduces the oxides of gold, silver, and platinum to the metallic state, completely precipitating them from their solutions.

BERZELIUS represented pyrogallic acid by the formula $C_6 H_3 O_3$, the equivalent of which is 63. STENHOUSE gives the composition as $C_8 H_4 O_4$. This statement is confirmatory of that made by CAMPBELL. The composition is as under:—

		Centesimally.	
	Atomic weight.	Theory.	Stenhouse.
8 Eqs. Carbon,	48	57·14	57·60
4 Eqs. Hydrogen,	4	4·76	4·78
4 Eqs. Oxygen,	32	38·10	37·62
1 Eq. Pyrogallic acid,	84	100·00	100·00

Of pyrogallic acid, so little is still known that it is even doubtful if it possesses acid properties, since a single drop of ammonia added to its solution rendered it alkaline, and caused it to assume a dark-brown color. According to STENHOUSE, it does not combine with alkalies. On adding to it an excess of ammonia, and evaporating *in vacuo*, the acid crystallized in dark-brown confused tufts, entirely free from the alkaline base.

By heating gallic acid to different degrees, and under various circumstances, many bodies are formed; as by heating gallic with sulphuric acid to 285°, and mixing the solution with water, the deposit of a red crystalline substance is caused, which has been termed *paraellagic acid*, its ultimate components being the same as those of ellagic acid before noticed. *Metagallic* or *melanogallic acid*, is formed when dry gallic acid is heated rapidly to 480°; carbonic acid and water are evolved; and, instead of pyrogallic acid being sublimed, a black, shining, and tasteless body is produced, insoluble in water, alcohol, and ether; dissolving in the alkalies; precipitated thence by acids in the form of a black powder; capable of expelling carbonic acid from the alkaline carbonates; neutral to vegetal colors; producing black deposits in solutions of lime, magnesia, lead, copper, iron, and zinc; its formula evidently being $HO, C_{12} H_3 O_3$, and the resulting equivalent 108. In combination its atomic weight is 99, and its composition—

		Centesimally.	
	Atomic Weight.	Theory.	Pelouze.
12 Eqs. Carbon,	72	72·72	72·86
3 Eqs. Hydrogen,	3	3·04	3·18
3 Eqs. Oxygen,	24	24·24	23·96
1 Eq. Anhydrous metagallic acid,	99	100·00	100·00

Melanotannic acid is obtained by heating a solution of tannic or gallic acid with excess of potassa in contact with the atmosphere, till a precipitate of gallic acid is no longer given on supersaturating the menstruum with acetic acid, with which it is then evaporated to dryness, and the black residue washed with dilute alcohol to remove the acetate of potassa. The product is then dissolved in water, acidulated with acetic acid, and thrown down by acetate of lead; a brownish-black compound falls, which, when dried, becomes pulverulent, and has the composition $2\ PbO,\ C_{14}\ H_4\ O_7$. BÜCHNER consequently represents melanotannic acid as $2\ HO,\ C_{14}\ H_4\ O_7$.—*Brande.*

When trying, for practical purposes, the difference of effect produced by the sesquisulphate and protosulphate of iron upon pure tannic and gallic acids, the changes produced with the former are somewhat similar to those which occur in a solution of galls. With gallic acid the sesquisulphate gives at first a black precipitate, not so dark as the tannate, but in a few minutes it changes to an olive, and continues to vary till it becomes almost colorless. With the protosulphate, at first the tinge is scarcely visible, but after an hour's exposure it assumes a rich violet. From these facts it may be concluded, that tannic is superior to gallic acid as a dyeing agent for black; moreover, the compound formed is less soluble.

Another circumstance which modifies the results of these experiments in their application to dyeing, is the quality of the water used. If the experiments be performed with distilled, it will be found on repeating them with common spring water, that one-half of the quantity of stuffs will give the same depth of color, and that, in this instance, there is more of a purple hue, and the colors are much more permanent. This may be illustrated by a very simple experiment. Take two glass jars of equal size, fill them half full with distilled water, and add an equal quantity of a solution of galls or sumac; put into each an equal number of drops of a solution of protosulphate of iron; the change is scarcely perceptible; but fill up one to the brim with spring water, and it almost instantly becomes a dark reddish-black. Allow both vessels to stand for an hour, the solution with the distilled water will have become a deep violet, while the other, notwithstanding the double quantity of water, is so dark that no light is transmitted; and it will require one-half more water to reduce it to the same shade as the other, but still retaining more of the reddish hue, which, however, makes it superior for black. It will also be found to be much more insoluble, and to require a greater proportion of acid to decompose it. If soft or filtered river water be used instead of distilled, the distinction is not so great; but still the difference is equal to one-half. The best water found for dyeing black and other colors darkened by sulphate of iron, which include drabs, fawns, slates, grey, some kinds of browns, blacks, *et cetera*, gave, by analysis, sulphuric, hydrochloric, and carbonic acids, lime, a trace of silica, and iron. The solid contents were in large quantity, but did not exceed one grain in a fluid ounce, or one hundred and sixty grains per gallon. These ingredients existed in the water as sulphate and carbonate of lime, chloride of calcium, and carbonate of iron; the latter was in very small proportion; the carbonic acid and lime greatest.

Now, a dyer learning his trade in an establishment where such water was used, could not fail to become successful with such colors as have just been recounted; but were he taken from it to another where soft filtered water was used, what would be the result? When he attempted to obtain a black with the same quantity of dye-stuff he formerly used, he would only produce a dark slate color; and if he wished to obtain slate, he would produce grey. In this dilemma, the dyer adds stuff till he comes to the desired shade; but fancy dyes bolstered up with stuffs are not so pretty; besides, the employer, in consequence of this addition, must either submit to a loss or discharge the workman, who, no doubt, would consider himself ill used, talk loudly of his ability in dyeing such colors, and offer to prove that the fault is not in him but in the water.

Dyeing being an art wholly dependent upon chemistry for its development and success, he who practises it without studying chemistry, is like a boy learning to repeat a number of choice sentences from an author without knowing his letters. Had the dyer, in such a case, known the principles of chemistry, so far as they are applicable to his trade, he would, on finding that the same quantity of stuffs did not yield similar results, have examined the water to discover where lay the difference, and in this instance he would find, that instead of employing an extra quantity of sumac, sulphate of iron, and logwood, to get a good black, the addition of a little chalk and hydrated sulphate of lime to the water, would so qualify it as to render it as effective as that to which he had been accustomed.—*Napier.*

INDIGO.—*Indigo*, French; *Indigo*, German.—This invaluable dye-stuff, for which no substitute has been found, was known to the ancients under the name *Indicum*, whence its modern appellation. In modern Europe, it first came into extensive use in Italy; but about the middle of the sixteenth century, the Dutch began to import and employ it in considerable quantity. Its general introduction into the dye-houses of both England and France was kept back by absurd laws,—see the historical notice at the commencement of this article,—founded upon an opinion that it was a fugitive substance, and even prejudicial to the fibre of wool.

Indigo is derived from a genus of leguminous plants found in India, Africa, and America, named *Indigofera.* Botanists have described about sixty species of this genus, all yielding indigo; but those from which it is usually obtained are the *I. anil*, the *I. argentea*, and the *I. tinctoria.* It is also extracted from a tree very common in Hindostan—*nerium tinctorium*—and from the woad plant—*isatis tinctoria*—which is a native of Great Britain, and of other parts of Europe. The coloring matter of these plants is wholly in the cellular tissue of the leaves, as a secretion or juice; not, however, in the blue state in which one is accustomed to see indigo, but as a colorless substance, which continues white so long as the tissue of the leaf remains perfect: when this is by any means destroyed, oxygen is absorbed from the atmosphere, and the principle becomes blue.

In the East Indies, after having ploughed the ground in October, November, and the beginning of December, the seed of the indigo plant is sown in the last half of

March or the beginning of April, while the soil, being neither too hot nor too dry, is most propitious to its germination. A light mould answers best; and sunshine, with occasional light showers, are most favorable to its growth; when much rain falls, however, the plants grow too rapidly, and do not sufficiently elaborate the blue. Twelve pounds of seeds are sufficient for sowing an acre of land. The plants grow rapidly, and will bear to be cut for the first time at the beginning of July; in some districts, even so early as the middle of June. The indications of maturity are the bursting forth of the flower-buds, and the expansion of the blossoms; at which period the plant abounds most in the dyeing principle: another token is taken from the leaves, the breaking across of which, when doubled flat, is accepted as a sign of ripeness; but this character is somewhat fallacious, and depends much upon the poverty or richness of the soil.

The first cropping of the plants is the best; after two months a second is made; after another interval a third, and even a fourth; but each of these is of diminished value. There are only two cuttings in America.

Two methods are pursued to extract the indigo from the plant: the first effects it by fermentation of the fresh leaves and stems; the second by maceration of the dried leaves—the latter process being deemed most advantageous.

In the indigo factories of Bengal, there are two large stone cisterns, the bottom of the first being nearly on a level with the top of the second, to allow the liquid contents to be run out of the one into the other. The uppermost is called the fermenting vat, or steeper; its area is twenty feet square, and its depth three feet; the lowermost, called the beater or beating vat, is as broad as the other, but one-third longer. The cuttings of the plant, as they come from the field, are stratified in the steeper, till it is filled within five or six inches of its brim. In order that the plant, during its fermentation, may not swell and rise out of the vat, beams of wood and twigs of bamboo are braced tight over the surface of the plants, after which water is pumped upon them till it stands within three or four inches of the edge of the vessel. An active fermentation speedily commences, which is completed within fourteen or fifteen hours, a little longer or shorter, according to the temperature of the air, the prevailing winds, the quality of the water, and the ripeness of the plants. Nine or ten hours after the immersion of the plant, the condition of the vat must be examined; frothy bubbles appear, which are at first white, but soon become grey-blue, and then deep purple-red. The fermentation is at this time violent, the fluid is in constant commotion, apparently boiling, innumerable bubbles mount to the surface, and a dense scum of a cupreous hue covers the whole. As long as the liquor is thus agitated, it must not be interfered with; but when it becomes more tranquil, it is to be drawn off into the lower cistern. Great care is required at this point of the operation, for should the fermentation be pushed too far, the quality of the whole indigo is deteriorated; it is even better to cut it short, in which there is indeed a loss of weight, but the article is better and the returns more profitable. The menstruum now possesses a glistening yellow color, which, when the indigo precipitates, changes to green. The average temperature of the liquid is commonly 85° Fahr.

As soon as the liquor has been run into the lower cistern, men are set to work to beat it with oars or paddles, about four feet long, called *busquets*. Paddle-wheels have also been employed for the same purpose. Meanwhile other laborers clear away the compressing beams and bamboos from the surface of the upper vat, remove the exhausted matter, set it to dry for fuel, clean out the vessel, and stratify fresh plants in it. The fermented plant still appears green, though it has lost three-fourths of its bulk in the process, or from twelve to fourteen per cent. of its weight, chiefly water and extractive matter.

The liquid in the lower vat must be strongly beaten for an hour and a half, when the indigo begins to agglomerate in flocks, and to precipitate. This is the moment for judging whether there has been any error committed in the fermentation, which must be corrected by the operation of beating. If the fermentation has been defective, much froth arises during the agitation, which must be allayed with a little oil, and then a reddish tinge appears. If large round granulations are formed, the beating is continued to make them smaller, if possible. Should they become as small as fine sand, the water at the same time clearing up, the indigo is allowed quietly to subside. In case the vat was over-fermented, a thick fat-looking crust covers the liquor, which does not disappear by the introduction of a flask of oil. In such a case the beating must be moderated. Whenever the granulations become round and begin to subside, and the liquor clears up, the beating must be discontinued. The froth or scum diffuses itself spontaneously into separate minute particles, which move about the surface of the liquor, and are marks of an excessive fermentation. On the other hand, a rightly fermented vat is easy to work; the froth, though abundant, vanishes as soon as granulations make their appearance. The color of the liquor, when drawn out of the steeper into the beater, is bright-green, but as soon as the agglomeration of the indigo commences, it assumes the color of Madeira wine; and speedily afterwards, during the beating, a small round grain is formed, the separation of which makes the water transparent, and causes the disappearance of all the turbidity and froth.

In order to hasten the precipitation, lime-water is occasionally added to the fermented menstruum in the progress of beating, but it is not indispensable, and has been supposed to deteriorate the indigo. Two or three hours after the agitation, the supernatant liquid is run off, and by its condition affords a good indication of the success of both the processes. A laborer then enters the vat, sweeps all the precipitate into one corner, and empties the more elutriated portion into a spout leading into a cistern, situated beside a boiler, twenty feet long, three wide, and three deep. When all the deposit is once collected, it is pumped through a bag, for retaining the impurities, into the boiler, and heated to ebullition. The froth soon subsides, and shows an oily-looking film upon the surface. The indigo is by this means not only freed from the yellow extractive matter, but enriched in the intensity of its color, and increased in weight. Some manufacturers, however, prefer retaining it at a moderate temperature throughout, and affirm that a deeper hue is produced. From the boiler the mixture is run, after two or three hours, into a general receiver, called the *dripping* vat, or table, which, for a factory with twelve pair of preparation vats, is twenty feet long, ten wide, and three deep, having a false bottom two feet below the top edge. This cistern stands in a basin of masonry, made water-tight with hydraulic cement, the bottom of which slopes to one end, in order to facilitate the drainage. A thick woollen web is stretched along the bottom of the inner vessel to act as a filter. As long as the liquid passes through turbid, it is pumped back into the receiver; but as soon as it runs clear, the latter is covered with another piece of cloth to exclude the dust, and percolation is allowed to proceed spontaneously. Next morning the drained magma is put into a strong bag, and squeezed in a press. The indigo is then carefully taken out, and cut with a brass wire into pieces of about three cubic inches each, which are exsiccated either in a stove upon boards, or in an airy room upon shelves of wicker work. During the drying, a whitish efflorescence appears upon the pieces, which must be carefully removed with a brush. In some localities, particularly on the coast of Coromandel, the desiccated lumps of indigo are allowed to effloresce in a cask for some time, and when they become hard they are wiped and packed for exportation.

The other method of extracting the indigo from the plant, differs from that described only in the first operations. Instead of putting the plant into the vat when newly cut, it is spread out to dry in the sun for two days, and then thrashed to separate the leaves from the stems. The former are kept until they have changed from a green to a bluish-grey or lavender color, after which they are put into the first vat with warm water, and kept stirred till the leaves are so completely wetted as to sink. The liquor is then instantly let off into the beating vat, where it is treated as already described.

Berthollet, in narrating the procedure in the fermenting vat, gives the following opinion:—In the first, a fermentation is excited, in which the action of the atmosphere does not intervene, since an inflammable gas is evolved. There probably results from it some change in the composition of the coloring particles themselves, but especially the separation or destruction of a yellowish substance, which gave to the indigo a greenish tint, and rendered it susceptible of the chemical action of other bodies. This species of fermentation passes into destructive putrefaction, because the indigo has a composition analogous to that of animal matter.

Dr. Ure states, that from some experiments made upon the gases given off during fermentation, they were found, when taken about the middle of the operation, to be composed centesimally of 27·5 of carbonic acid gas, 5·8 of oxygen, and 66·7 of nitrogen; and towards the end of the process, they consisted of 40·5 of carbonic acid gas, 4·5 of oxygen, and 55 of nitrogen. No carbide of hydrogen seems to be disengaged. He adds that the fermenting leaves apparently convert the oxygen of the air into carbonic acid, and leave its nitrogen free. They also evolve a quantity of carbonic acid spontaneously. It will be observed, remarks Napier, that these two opinions are decidedly contradictory; the one says that the action of the atmosphere does not intervene, and that an inflammable gas is set free; the other, that there is no inflammable gas evolved, and that the air is apparently the principal agent in effecting the various changes. But when it is recollected that the leaves are all under the liquor, and kept so by the fixed position of the beams, there can be little contact between the fermenting leaves and the air, except that held by the water and among the leaves, and that of the plants themselves; hence the conversion of its oxygen into carbonic acid gas must be limited.

Sir Robert Kane says of this process:—After some time a kind of mucous fermentation sets in; carbonic acid, ammoniacal and hydrogen gases are evolved, and a yellow liquor is obtained, which holds the indigo dissolved. The theory of this action is, that by the putrefaction of the vegeto-animal matter of the leaves, the indigo is kept in the same white soluble condition in which it exists in the plant.

Dr. T. Thomson supposes that the indigo exists in the plant in union with another substance, which during fermentation is decomposed, and carbonic acid gas consequently evolved. To quote his own words:—The leaves of the indigofera yield a green infusion to hot water, and a green powder may be precipitated from it; but unless a fermentation has taken place, neither the color nor the properties have any resemblance to those of indigo. There is little doubt that in the leaves it exists in the state of white or *deoxidised indigo*, and that, during the fermentation, it combines with the requisite quantity of oxygen to convert it into *blue indigo*. The evolution of carbonic acid gas renders it not unlikely that the *white indigo* was in combination with some principle—probably of an alkaline nature—which was decomposed during the fermentation.

It is obvious from these discrepancies of opinion relative to the nature of the metamorphoses which occur during fermentation, that investigations have not been instituted into this part of the process to so full an extent as would seem to be required, and hypotheses advanced upon statements concerning the gases given off must be as unsatisfactory as they are hazardous. The supposition of Dr. Thomson, says Napier, and the Editor agrees with the opinion, appears to be best supported: deoxidised indigo readily unites with alkaline substances, and, as alkaloids generally contain nitrogen, the evolution of that gas either free, or in combination with hydrogen and oxygen, forming ammonia, can readily be credited. Napier suggests that indigo, when fully examined, may, like gallic acid, be found to be the result of some complicated decomposition, and not, as is now generally received, pre-existent in the vegetal.

The reactions which occur during the beating are more easily elucidated, and though this point, like most others, has had its quota of dubitable assertions, yet the discrepancies of the various statements are not so numerous. Dr. Ure says:—The object of the beating is threefold: first, it tends to disengage a great quantity of carbonic acid present in the fermented liquor; secondly, to give the newly developed indigo its requisite amount of oxygen by the most extensive exposure of its particles to the atmosphere; and, thirdly, to agglomerate the indigo in distinct flocks or granulations.

Manufacturers know well that sunshine aids in the separation of the indigo from the liquor. The absorption of oxygen, as the indigo is thrown down during the agitation, seems to be well established by direct experiment. From all these facts, however, no standard information regarding the changes occurring in the vat seems to be furnished. Indigo, whether in an oxidised or deoxidised state, is insoluble in water, and there must be some principle which retains it in solution previous to the beating. The only substances at present known as being capable of liquefying white or deoxidised indigo, are the alkalies and alkaline earths. But, says NAPIER, during such a generation and emission of carbonic acid gas, the existence of any known alkaloid capable of holding the indigo in solution is next to impossible, and results prove the contrary; for, while the acid is liberated, the indigo becomes insoluble, a result just the opposite of what one would conceive to occur in the presence of an alkaline substance, except it be supposed either that the carbonic acid arises from the decomposition of the alkaloid, or that it is evolved from *some substance which is being resolved into indigo.*

Indigo, as it occurs in commerce, is usually met with in cubical lumps or cakes, friable, more or less brittle, and of various shades of a peculiar deep-blue, passing into violet-purple. When rubbed with a smooth hard body, it acquires a beautiful glossy and cupreous appearance, and always affords, on grinding, an intensely blue powder. Its specific gravity is sometimes greater, but at other times less, than that of water; this depends principally on its admixture with, or freedom from, foreign matters, but also upon the treatment of the paste in the operations of boiling, pressing, and drying. The best samples are those which are lightest and most copper-colored.

CHEVREUL has so minutely described the numerous varieties of commercial indigo, as to preclude the necessity of presenting the reader with details of their physical appearance from any other source.

Indigoes prepared in Asia will first be noticed; they are from Bengal, Coromandel, Madras, Manilla, and Java.

The trade in Bengal indigo is chiefly carried on in Calcutta, and through the medium of the East India Company; its varieties are very numerous. The principal, commencing with those of the best quality, are the following:—1. The superfine or light blue. This is in a cubical form, light and friable, soft to the touch, of a clean fracture, and giving a beautiful copper color on being rubbed with the nail. 2. Superfine violet. 3. Superfine purple. 4. Fine violet, in color a little less brilliant than the superfine, and rather heavier. 5. Fine purple violet. 6. Good violet, somewhat heavier than the fourth quality. 7. Violet red. 8. Common violet. 9. Fine and good red, heavier than the preceding, and the hue of which borders decidedly on red. 10. Good red, of a firmer and more compact structure. 11. Fine copper-colored, redder, and still more dense. 12. Middling copper-colored. 13. Ordinary and low copper-colored; this is of a cupreous tinged blue or red, somewhat difficult to break.

Coromandel indigoes of the best quality correspond to those of Bengal of medium value, and are met with in square masses, having an even fracture, but are more difficult to break; indeed, these are harder to disrupture than any other variety. The inferior kinds are heavy, of a sandy feel, having a blue color bordering on green, grey, or even on black; they are not unfrequently found having a greenish-grey hue.

The productions of Madras have a grained rough fracture, and are of a cubical figure. The superior qualities have no rind, in form they somewhat resemble that of a *hat*, and are more light and friable than those of Coromandel. These kinds, when of the best quality, are very light, though not equal in this respect to the superfine blue of Bengal. The middling classes have a very slight copper tinge. The color of the inferior qualities is a dark or muddy blue, black, or even grey, and greenish.

The Manilla indigoes present the mark of the rushes upon which they have been dried. They are of a closer consistence and lighter hue than those of Madras, but not so compact as the produce of Bengal. The better qualities are often in flat and elongated masses, somewhat porous, and consequently light. Medium kinds are of a violet color, but are inferior to the violet of Bengal.

Java indigo occurs in flat square masses, sometimes of a lozenge shape. The superior qualities appear as fine as the blue, violet, or red indigoes of Bengal, but they are not so in reality.

Indigo prepared in Africa next come under consideration. They are from Egypt and Senegal:—

The superior classes of Egyptian indigo are superfine and fine violet blues. They are light, but their structure is not very compact, and they often contain sand. The squares are rather flatter than those of Bengal.

Senegal indigoes are of good quality, but contain more earthy matter than any others in the trade.

The indigo from America are those of Guatemala, Caraccas, Mexico, Brazil, Carolina, and the Antilles.

The indigoes of Guatemala, of the Caraccas, and of Mexico, are of various kinds. The best are of a bright blue color, remarkably light and fine. These are esteemed equal to the best Bengal. The inferior qualities are of a violet hue, but, in general, are more mixed than the Bengal kinds.

The Brazil indigoes are in small rectangular parallelopiped masses, or in irregular lumps, of a greenish-grey color externally, having a smooth fracture, a firm consistence, and a cupreous tint of greater or less brilliancy.

The Carolina product is in small square masses, having a grey exterior. The best qualities have a dull copper color, bordering on violet or blue. The common kinds are almost always of a greenish-blue; they are rarely found of a cupreous hue.

The principal varieties of indigo in commerce are the Bengal, the Caraccas, the Guatemala, the Madras, and the Manilla.

The buyer should be on his guard against certain defects, of greater or less consequence, and which depend on causes acting either on the indigo when already prepared, or else occurring during its preparation. The following are some of the characters to be borne in mind:—The large or small fracture; squares of indigo reduced by accident into lumps of variable size; fragments; squares abraded so as to be fine enough to pass through a sieve; sometimes, also, squares are met with which are readily broken, and which present a whitish kind of mouldiness in their interior; gritty lumps, throughout which are points presenting the appearance of granite; streaky masses, in which are layers of various shades of blue, placed one above the other, in the same square; pieces of a scorched appearance, which, on being sharply rubbed between the hands, are ground into small fragments, nearly black in color; sandy lumps, in the interior of which the eye can detect shining specks, which are nothing more than sand.

Indigo is insoluble in water, ether, hydrochoric acid, sulphuric acid in a dilute state, cold alcohol, and in ethereous and fat oils; but the latter liquids when boiling take up a small amount of it, which they deposit on cooling. Creosote has the property of dissolving it.

The commercial value of indigo is dependent upon the amount of pure indigo—indigo-blue—which the various kinds may contain: the average proportion is about fifty per cent. Chevreul prescribed a method for the rough analysis of indigo, by exposing it successively to the action of water, alcohol, and hydrochloric acid. One hundred parts of Guatemala indigo, thus treated, gave,

To water	Green matter combined with ammonia,	12
	Deoxodised indigo,	
	Extract,	
	Gum.	
To alcohol	Green matter,	30
	Resin,	
	A trace of indigo	
To hydrochloric acid	Red resin,	6
	Carbonate of lime,	2
	Oxide of iron,	2
	Alumina.	
Residue	Silicic acid,	3
	Pure indigo	45

Some chemists consider that the only method of accurately determining the value of this article consists in removing the various impurities by the successive action of dilute acid, caustic alkali, alcohol, and water, and then ascertaining the quantity of indigo-blue that remains, the ash being deducted in the usual manner. Others, again, prefer the process of reducing the indigo-blue by deoxidising agents, and afterwards precipitating and collecting it in the pure state. This method was adopted about the commencement of the present century by Pringle, who employed the well known materials, sulphate of iron and lime, as the reducing and dissolving agents, and separated the indigo-blue from the clarified solution with hydrochloric acid. The operations involved in this process are exceedingly tedious, and in consequence of the peculiar property which reduced indigo has of forming two distinct combinations with lime, the one soluble and the other insoluble, the results afforded by it are not always satisfactory.

Dana has recommended another method, based, however, on the same principle. It consists in boiling the indigo in caustic soda, and cautiously adding protochloride of tin until the indigo-blue is completely reduced and dissolved; the clear solution is then precipitated with bichromate of potassa, and the subsidence, being well washed with dilute hydrochloric acid, is dried and weighed.

Fritzche has suggested grape-sugar, alcohol, and caustic soda for the reduction and solution of the indigo-blue. His process appears, however, to be better adapted for the preparation of pure indigo than for testing its value; indeed, for the former of these purposes, Berzelius has spoken of it in the highest terms. It is as follows:—Four ounces of finely powdered indigo, and the same quantity of grape-sugar, or honey, are mixed with a little alcohol having a specific gravity of 0·860, and the whole is put into a bottle of ten pounds capacity; six ounces of a concentrated solution of caustic soda are then added, the bottle is filled up with hot alcohol, well stopped, shaken, and then set aside. After the lapse of some hours, the clear red fluid is siphoned from the insoluble deposit into another bottle, the mouth of which is loosely covered, so as to allow the admission of air. In the course of a few days the indigo-blue falls down, and, after having been separated, it is washed first with alcohol, and finally with hot water.

Chevreul's method of dyeing cotton until the indigo solution is exhausted, is, obviously, extremely objectionable

Reinsch, after trying various modes, prefers that of dissolving a grain and a half of the indigo in concentrated sulphuric acid, and estimating its value, comparatively, by the quantity of water required to reduce the color of the solution to a certain shade. This process, which is both simple and convenient, differs in no respect from that long since applied by Ure.

Labillardière determined the commercial value of indigo by means of an instrument to which he gave the name of *colorimeter*, and which consists of two perfectly cylindrical glass tubes, each closed at one end, about half an inch in diameter, and from thirteen to fourteen inches long. These must be made of the same glass, and of the same bore and thickness. At about five-sixths of their length from their closed ends, they are divided into two parts of equal capacity, the second half being graduated into one hundred divisions. The tubes are then placed in a small wooden box, through two contiguous openings in its upper part; immediately behind them, two square holes, or slits, corresponding to their diameters, are cut, whilst the other end of the box has an eye-hole, so that by holding the whole before the light, and looking at the tubes through the eye-hole, the difference of hue of the colored liquor put into the tubes may be easily appreciated. The inside of the box should be blackened.

The *modus operandi* is as follows:—Take a sample of each parcel of indigo to be examined, reduce them separately to a fine powder by triturating and sifting; weigh off twenty grains of each, and introduce that quantity into a small matrass perfectly clean and dry; pour upon it four hundred grains of sulphuric acid of specific gravity 1·845, and leave the whole exposed to a gentle heat of about 100° or 110° Fahr. for about an hour, shaking the vessel from time to time, in order to promote the solution. When this has occurred, and the menstruum has become cold, the whole is emptied into a large glass bottle capable of holding four pints, stirring it well with a glass rod; the matrass should be well rinsed with water, which is to be poured into the bottle, and more is added until the latter is completely filled up. Take now ten thousand grains of this liquor and pour them into a glass beaker, which should be left at rest for a few hours, so that any solid matter held in suspension may fully subside. The rest of the liquor, not being used, may be thrown away.

If several samples of indigo have to be tested, they must all be examined at the same time and in the same manner.

The clarified solutions are then poured into the respective colorimeter tubes till filled up to 0°; the latter are then introduced into the apertures in the box, and the shade is examined by looking at them through the eyehole opposite; if a difference in the depth of the color is observed, water is added to that which is the deeper of the two; the opening of the tube being well closed with the finger, the liquid is well shaken and the tube is replaced, water being added, if need be, until both correspond. By looking at the graduations to which water has been added, the operator knows at once the difference or relative tinctorial power of the two samples examined, for it is evident that the indigo which has required the greater quantity of water to reduce it to the same pitch or intensity of color as the other, is richer or of greater value.

Bolley proceeds in the following manner:—One gramme of indigo is rubbed to a fine powder in a porcelain mortar, about ten grammes of fuming sulphuric acid are poured over it, and the mixture left covered from six to eight hours, being occasionally stirred. After this time the whole is removed into a strong evaporating dish, containing two pounds of water; fifty grammes of strong hydrochloric acid are added, and the whole is heated to ebullition over a spirit or gas lamp. The water which escapes during the evaporation is from time to time replaced. A solution of chlorate of potassa is now made as follows:—One fourth of a gramme of the warm powdered dry salt is dissolved in one hundred grammes of water in a graduated cylinder capable of containing several decimètres of water. This quantity of chlorate suffices even for the very best kinds of indigo. At first, several decimètres of the solution may be added at once, but subsequently only one degree at a time, and the mixture boiled between every addition. The liquid passes from blue into green, brownish-green, and lastly into brownish-red. Any one who has once made the experiment will not fail to observe the right moment when to stop, that is, when the liquid has lost the last tint of greenish-brown, and turns reddish-brown. To insure certainty, it is well to make a mark with a glass rod, moistened in the gradually changing solution, upon a strip of white filtering paper.

The values might, by calculation, or a different arrangement of the apparatus, be reduced to those of pure indigo-blue; but that appears useless, as the latter is not an article of commerce, and the consumer or purchaser is satisfied when he has ascertained the value of the samples as compared with kinds known by him to be good.

An apparently simple, and not less ingenious method, proposed by Dr. Penny, is based upon the circumstance that indigo-blue, in presence of hydrochloric acid, is decolored by bichromate of potassa. This salt has long been used for discharging indigo-blue and other colors in the printing of textile fabrics, as well as for bleaching oils, fats, and various substances. In employing it for estimating the comparative value of commercial indigo, the necessary manipulations are extremely simple.

Ten grains of the sample, in very fine powder, are carefully triturated with two drachms, by measure, of fuming sulphuric acid, and the mixture, being excluded from the air, is allowed to digest, with occasional stirring, for twelve or fourteen hours. A flat-bottomed flask, with a lightly-fitting cork, is a very convenient vessel for this operation. A few fragments of broken glass should be thrown in to facilitate the contact of the indigo and acid during the agitation, thus preventing the aggregation of the former into small clots, which the acid of itself cannot penetrate. If a small capsule or testing glass be used, it should be covered, during the digestion, with an air-tight glass jar. It will also be found advantageous to place the mixture in a warm situation, say between 70° and 80°, so that the action of the acid may be fully developed; a higher temperature than this must be avoided, as sulphurous acid is liable to be produced, and the trial in consequence completely vitiated. Great care must be taken to insure the perfect solution of the indigo-blue in the acid. This being accomplished, the solution is poured slowly, with constant stirring, into a pint of water contained in a basin, and three-fourths of an ounce—fluid measure—of strong hydrochloric acid immediately added, the vessel being rinsed clean with water.

An alkalimeter of one hundred equal measures is now made up, in the usual way, with seven and a half grains of dry and pure bichromate of potassa, and the solution added in small successive portions to the diluted sulphate of indigo in the basin, until a drop of the mixture, on being placed on a white slab, or on bibulous paper, presents a distinct light brown or ochreous shade, unmixed with any blue or green. The process is then finished; the number of measures of bichromate used is read off, which shows the comparative value of the indigo subjected to the trial.

In applying the test drop to the bibulous paper, the best results are obtained by bringing the end of a glass rod into contact with the indigo solution, and then gently pressing it against the surface of the paper. The stain thus produced will be circular, and conveniently localised to a small space. By using bibulous paper, it will also be found much easier to recognise the last traces of the blue color than when a slab is employed, and the results, when dry, may be preserved unchanged for reference or comparison.

It is advisable to keep the indigo solution gently heated while the test-liquor is being added; and it is essentially necessary that the mixture should be well stirred after each addition. Several measures of the test-liquors may at first be poured in without risk of error, but, towards the conclusion, the manipulation must be slow and careful, as one or two drops will then be found to produce a very decided effect. The characteristic changes of color which the mixture undergoes will distinctly indicate the approach of the process towards completion. The blue shade of the solution gradually diminishes in intensity, becoming perceptibly lighter and lighter, after a time acquiring a greenish tinge, which soon changes to greenish-brown, and almost immediately to light ochre brown.

This process, like many others apparently simple in description, is, so far as experience goes, not a reliable one in the hands of the mere practical man; it has often been tried, and as often laid aside with feelings of disappointment from the difficulty of finding the point of decoloration, and the deepening of the color by time, *et cetera.*

SCHLUMBERGER'S test consists in dissolving the indigo in fuming sulphuric acid—Nordhausen oil of vitriol—and decoloring the solution, previously diluted with much water, by chloroxide of calcium—bleaching powder—as this acts only on the blue coloring substance, and not at the same time on the various other bodies which indigo contains. The quantity of bleaching powder requisite to produce decoloration accurately agrees, as will be subsequently seen, with the amount of tinctorial matter.

The operations are as follow:—A portion of pure indigo, or indigo-blue, is prepared by removing the scum which is continually found on the *blue vat*, treating it with an excess of dilute hydrochloric acid, washing the deposit until all soluble parts have been removed, then drying and preserving it in well-closed bottles to protect it from all changes in the moist state. When no blue vats are at hand, a mixture is made of three parts of newly-slaked lime, three parts of sulphate of iron, one of indigo rubbed fine with water, and fifty of water. These are frequently stirred for some hours and left to subside, so that the clear liquid may be poured off; this is then violently agitated in order to bring it into contact with the atmosphere, and cause the separation of the whole of the indigo. The precipitate thus obtained is treated with dilute hydrochloric acid in the same manner as is described for the blue vat. In all subsequent experiments, this pure indigo serves as a standard of comparison with the results which the various kinds of indigo submitted to the test afford, and taking the pure indigo as one hundred, the value of the tested indigo is expressed by numbers which indicate the per centage of pure coloring matter. In each case the standard indigo is used for comparison with that of commerce, as it is then not requisite to determine previously the amount of chloroxide of calcium in solution, besides which the experiment is more accurate. In this instance the causes of the differences in the results depend on circumstances, which always remain the same whether the standard indigo is employed, or indigo, the purity of which is unknown. One gramme of each kind is weighed off, which must be finely ground. This is placed in a dish, and twelve grammes of fuming sulphuric acid added to it by means of a graduated pipette. The mixture is now rubbed together, the dish placed for four hours at a temperature of from 122° to 140°; or, what is preferable, for the sake of accuracy, it is transferred, well covered, to a place in which the temperature is about 68° to 78°.

Meantime as many glasses—each holding about a quart—as there are sulphate solutions, are filled with distilled water, and to each sample of indigo is added its equal volume of water from the glass. The liquids become warm, upon which they are well stirred again; water is then gradually added until the vessel is full, when the whole is poured into the glass, and the dish washed with a portion of the water. A solution of bleaching powder is now prepared, of 2° Twaddle—specific gravity 1·010—in strength, and a given quantity, say ten graduations of the alkalimeter, taken.

The well-stirred blue solution of the sulphate of indigo is now measured in a burette, and a portion poured into a dish, agitated thoroughly, and the entire quantity of the bleaching powder contained in the measure added at once. If the liquid immediately assumes a yellow color, it is a sign of an excess of the decoloring agent, and sulphate of indigo is added by degrees until a faint olive-green hue is obtained. The experiment is now repeated, and the quantity of chloroxide of calcium, which had been found necessary in the first case, added to the quantity of sulphate of indigo; so that with one single mixing, there being neither an excess of chloroxide nor sulphate of indigo, the liquid acquires that tint at once. But when, after the first mixture, the menstruum has retained a blue color, which is a sign of an excess of the sulphate of indigo, fewer degrees of it are taken, until the requisite tint has likewise been attained with a single mixing.

When the several indigoes have been treated in this manner, the following calculation is made to obtain the true value of the sample which has been examined; the goodness of the indigo being in inverse ratio to the quality of sulphate employed.

Suppose it were found that *pure* indigo required fifty-four parts of its sulphate solution to be decolored by the fixed quantity of bleaching powder, and that, on the other hand, the indigo under examination required sixty-four parts of its sulphate solution; then, according to the proportion,

$$64 : 54 : : 100 : x = \frac{100 \times 54}{64}$$

or 84·4, which indicates the quantity of indigo-blue contained in one hundred parts of the sample examined.

It is important, for the accuracy of the experiment, that the pure indigo, and the various kinds submitted to the test, should be equally moist, and it is therefore requisite to enclose all the samples, as soon as they are taken out of the chests, in stoppled bottles, to prevent any difference in the amount of moisture previous to weighing. When a chest contains several kinds of indigo, which exhibit only a slight variation in their tints, a few pieces are selected from the several lots, powdered together, and the mean result taken as the correct one. But when, as often happens, a chest contains pieces of indigo of entirely different hues, it is best to examine the mixed sorts separately.

SCHLUMBERGER dilutes both the solution of sulphate of indigo and that of the bleaching powder, since the experiment in this manner is less exposed to error than when concentrated menstrua are operated upon; besides, it is easier when the liquid is only faint blue to distinguish when the addition must be discontinued.

Impure water, or such as contains salts of lime, produces a more or less considerable precipitate of the blue substance, mixed with sulphate of indigo; it is, therefore, necessary to employ distilled water.

The purer the indigo, and the more complete its solution, the easier is it to ascertain the last stage of decoloration, or the point at which the test is completed; and in this case it is evident how sensitive the reaction of the bleaching powder is on the indigo; for a solution of the latter, to which an excess of chloroxide of calcium has been added, and which is therefore yellow, is rendered blue by a single degree of the indigo solution, a proof that this method will indicate half a per cent. In the commercial kinds of indigo it is less easy to fix the point at which decoloration must be discontinued, for in this case the bleached liquid assumes an olive hue, and from two to three degrees of the indigo solution must be added to change the yellow color into the blue.

The author of this method prefers taking a fixed quantity of chloroxide of calcium, and varying that of the sulphate of indigo, to making the latter a fixed quantity, and allowing the decoloring agent to be diminished or increased, from its being possible to dilute the indigo solution with much water, and so render the quantity of matter in each measure of it so small as will necessarily cause the saturation of the bleaching liquor to be approached by minute and delicate portions.

Wittstein advocates the use of deoxidation tests above all others, and considers that any discredit into which it has fallen, is the result of unfounded prejudice. He also objects to the use of sulphuric acid as a solvent of indigo in testing, as that acid takes up other constituents of the indigo, and, at least, it is only a comparative test, and argues that the reduction test is not only a comparative, but an absolute and tangible result, when a few necessary precautions are taken, and gives the following directions:—

Ten grains of indigo are rubbed with water in a porcelain mortar; to this, twenty grains of hydrate of potassa are added, together with a few drops of water—the trituration being continued—and then forty grains of sulphate of iron. The mass is mixed with water, so as to form a thick paste, and introduced into a six ounce stoppered bottle, which has been previously weighed; the mortar should then be rinsed, and the bottle nearly filled up with water. After inserting the stopper, the whole is weighed, and well shaken for some time. After the lapse of a few hours, the indigo is deoxidised and dissolved. The mixture is then allowed to settle, the clear liquid is poured into a glass cylinder as completely as possible, and the bottle again weighed. The liquid is now treated with hydrochloric acid, the blue precipitate collected upon a weighed filter, washed with water, dried and weighed. By means of a proportion, it may be ascertained how much indigo-blue is contained in the indigo taken: if, for instance, the contents of the bottle weighed 3140 grains, the residue left on decantation, 535 grains, and the 2605 grains of clear liquor yielded 2·5 grains of indigo-blue; then,

$$2605 : 3140 :: 2{\cdot}5 : = 3{\cdot}01;$$

consequently, the indigo examined would contain 30·1 per cent. of pure coloring matter.

Berzelius, in 1827, made an investigation of indigo, and resolved it into four distinct bodies—*gluten*; a *brown matter*, having an apparent resemblance to extract; a *red substance* which, when heated in a close vessel, affords a grey sublimate; lastly, *indigo-blue.*

The matter by him termed gluten is dissolved both by alcohol and water: it was procured by digesting powdered indigo in dilute sulphuric acid, filtering the menstruum, evaporating it to dryness, and macerating the residue in alcohol.

The brown substance was taken up from the indigo—freed by the above procedure from gluten—by potassa, and was precipitated by sulphuric acid.

The indigo, thus acted upon by the acid and by potassa, was digested in alcohol, which abstracted a red principle, soluble in concentrated sulphuric and in nitric acids, but left intact by water and by alkalies, and which, when heated *in vacuo*, yielded a grey crystalline sublimate.

The residue, after these operations, is, with the exception of a small quantity of silicic acid, the true tinctorial matter of indigo—indigo-blue—and is the principle which affords a purple vapor and sublimate when indigo is heated.

In order to obtain perfectly pure indigo-blue, **Berzelius** treats the commercial product successively with hydrochloric acid, weak solution of potassa, and hot alcohol, to remove the foreign matters above mentioned; the remaining indigo-blue is then thoroughly mixed with twice its weight of freshly-slaked lime, and the mixture put into a bottle capable of holding one hundred and fifty times the quantity of the substance operated on; the bottle is then filled up with boiling water, and four parts of crystallized protosulphate of iron added for every three of indigo; it is then securely stopped, and having been thoroughly agitated, is set aside for several hours. In this way the indigo-blue, which is insoluble, is converted into indigo-white, which dissolves in the lime water, producing a yellow liquor, which is then poured off, mixed with dilute hydrochloric acid, and left for a long time exposed to air; the acid retains the lime and other substances in solution, while the indigo-blue is deposited, and may be freed from hydrochloric acid and chloride of calcium by washing in water.

If indigo-blue be heated to about 550°, it gives off beautiful reddish-violet fumes, which adhere to the sides of the vessel, or to the upper surface of the resulting charcoal, in long needle-like crystals. **Walter Crum** of Glasgow, whose investigations have materially elucidated the chemical nature and properties of indigo, uses for its sublimation two shallow platinum capsules about three inches in diameter, and of such depth that when placed together with their concave surfaces inwards, they are about three-eighths of an inch asunder in the centre. In the middle of the lower capsule are placed about ten grains of coarsely pulverised indigo, the cover is put on, and the flame of a spirit-lamp cautiously applied; vapor is soon disengaged with a sibilant noise, when this discontinues, the heat is removed, and the whole allowed to cool. The sublimed indigo will be found, in a crystalline state, principally upon the inner surface of the cover, though a little will remain upon the charred matter. In this manner from eighteen to twenty per cent. of the indigo employed were obtained.

TAYLOR'S process, by which seventeen or eighteen per cent. has been procured, is as follows —

A quantity of indigo is reduced to powder, mixed with about half its weight of sulphate of lime, and so much water added as will bring the whole to a thin paste. This is spread evenly, in the form of a strip about two inches broad, upon an iron plate, to the depth of one-eighth of an inch, and allowed to remain exposed to the air, or to a gentle heat, till it is tolerably dry If the heat of a spirit-lamp be now applied to the under-part of the plate, fumes possessing a disgusting odor are evolved, and in a few minutes the indigo is covered with a dense purple-red vapor, which condenses into brilliant flattened prisms or plates, of an intense copper color, forming a thick velvet-like coating over the surface immediately exposed to heat. When this ceases to appear the heat is withdrawn, and when cold, the sublimed crystals may be readily swept off, without in the least disturbing the subjacent mass.

According to CRUM, the processes of BERZELIUS and FRITZCHE yield pure indigo of a deep blue, but, at the same time, cupreous hue, and not unfrequently having a slightly crystalline appearance. When obtained, on the contrary, by means of heat, it forms flat needles and four-sided prisms, which, when seen at a particular angle, have a peculiar and intense copper color, but when lying in heaps, are of a rich brown. Occasionally the crystals are in broad, thin plates, which, when viewed by transmitted light, are of a splendid blue. The points at which it fuses, sublimes, and is decomposed, approach very nearly to each other. Its vapors somewhat resemble those of iodine; they are translucent, and possess a fine reddish-violet tint. When the crystals of indigo-blue are subjected to heat in communication with the atmosphere, they sublime without residue, in close vessels, as the temperature rises, the fumes acquire a scarlet hue, and then become orange-colored; a small quantity of a *peculiar basic empyreumatic oil*—anilin—is also formed, and carbonaceous matter deposited. Sublimed indigo-blue has a specific gravity of 1·35.

The composition of pure indigo was first ascertained by CRUM, and his results have been confirmed by DUMAS, as also by ERDMANN and LAURENT. Its formula, as generally accepted, and as deduced from the analyses of the above chemists, is $C_{16} H_5 O_2 N$.

	At. weight	Centesimally represented.				
		Theory.	Crum	Dumas	Erdmann.	Laurent.
16 Eqs. Carbon,....	96	73·28	73·22	73·28	73·99	73·30
5 Eqs. Hydrogen,..	5	3·82	2·92	3·82	3·80	3·88
2 Eqs. Oxygen,....	16	12·21	12·60	12·21	11·56	22·82
1 Eq. Nitrogen,..	14	10·69	11·26	10 69	10·65	
1 Eq. Indigo-blue,	131	100·00	100·00	100 00	100·00	100·00

Indigo-blue is tasteless and inodorous, and is perfectly neutral, giving neither acid nor alkaline reaction. It is completely left intact by water and ether; a trace of it is abstracted by boiling alcohol. Hot olive oil and turpentine acquire from it a blue tint, but on attaining the temperature of the atmosphere, the fractional portion which they had seemingly dissolved, is deposited. Dilute acids and solutions of alkali have no effect upon it.

If pure indigo be brought into contact with deoxidising agents, it is rendered white, and has the new property of dissolving in alkalies. Phosphorus, sodium, calcium, phosphites, sulphites, sulphides of potassium, *et cetera*, protoxides of iron and tin, sugar, starch, tannic acid, *et cetera*, from their attraction for oxygen, all possess this attribute.

LIEBIG obtains *indigo-white* by adding hydrochloric acid to the yellow liquor procured by the action of lime and protosulphate of iron upon common indigo and water, preventing access of air both before and after the addition. The precipitate is well washed with newly-boiled water, or with a dilute solution of sulphurous acid, then drained as rapidly as possible on a filter, and dried *in vacuo*.

BERZELIUS siphons the yellow menstruum above mentioned, into a stoppered bottle previously filled with hydrogen or carbonic acid gas, and containing some acetic or dilute hydrochloric acid, the siphon itself being previously filled with water deprived of air. Under these circumstances, a white, flocculent, and often crystalline precipitate falls; it should be carefully excluded from contact with the atmosphere, and allowed to settle; the supernatant liquid must then be decanted, the subsidence collected upon a filter in an atmosphere of hydrogen or of carbonic acid, edulcorated with water freed from air, pressed in folds of bibulous paper, and dried *in vacuo*.

The composition of indigo-blue, from the analyses already cited, is represented by $C_{16} H_5 O_2 N$; that of indigo-white, according to DUMAS, the accuracy of whose results has never been questioned, is $C_{16} H_6 O_2 N$; so that the only difference between them is one equivalent of hydrogen. With regard to their rational formulæ, two distinct but ingenious hypotheses have been suggested. In the first of these, *indigo-white is accepted as the hydride of indigo-blue*, and the relation has been compared to that of benzil and its hydride; thus—

Oxide of benzil, $C_{14} H_5 O_2$,	Indigo-blue, $C_{16} H_5 O_2 N$.
Hydride of oxide of benzil, $H, C_{14} H_5 O_2$..........	Indigo-white, $H, C_{16} H_5 O_2 N$.

LIEBIG stands at the head of those who are favorable to the other view, which infers that *indigo-white is the hydrate of a body having one equivalent less oxygen than indigo-blue;* in other words, a compound $C_{16} H_5 O N$ is supposed to be a base, of which indigo-blue is an oxide, and indigo-white a hydrate; thus—

Indigo-blue,................ $C_{16} H_5 O N + O$.
Indigo-white,................ $C_{16} H_5 O N + H O$.

The production of indigo-white by the agency of grape-sugar strongly supports the latter inference, for were indigo-white a hydride of indigo-blue, it could only be formed, in this instance, by the decomposition of water, the hydrogen of which would combine with the indigo-blue, while its oxygen would again unite with the hydrogen of the sugar, and it is highly improbable that oxygen should separate from the hydrogen of one body to unite with it in another.

It is further obvious, says **Brande**, that as concerns these compounds, a common radical, *anyl*—$C_{16} H_5 N =$ An—may be assumed as their basis. In such case, indigo-white would be a *hydrate of the protoxide of anyl*, An O, H O; while indigo-blue would be a *binoxide of anyl*, An O_2.

Indigo-white is insoluble in water and in dilute acids, but dissolves in alcohol, ether, and alkalies, to which it imparts a yellow tinge; the solutions, if exposed to the air, gradually combining with oxygen, and depositing indigo-blue. When pure, it would be perfectly white, but as known hitherto, it has always a greenish or bluish tint. When moist, it rapidly passes, under atmospheric influence, into blue; and when exsiccated acquires that hue to a greater or less degree. Even *in vacuo* this change slightly occurs, owing probably to the air still retained in the pores of the substance. When slowly heated in the air, it speedily becomes dark purple, and is converted into indigo-blue.

The solutions of indigo-white in alkalies cause precipitates with many metallic salts. These deposits, when not blue at first, become so on exposure. According to **Runge**, the subsidence occasioned by indigo-white in solutions of sesquioxide of iron, affords, when heated, a green sublimate; that formed with salts of oxide of copper being yellow; with silver-salts, orange-yellow; and the one with binoxide of mercury, grass-green; all of them having a crystalline texture. These results require a more minute investigation, especially as they differ from those of other chemists.

If an aluminous menstruum be precipitated by an alkaline solution of indigo-white, the deposit readily becomes blue, and if collected on a filter and exsiccated, it glitters as if crystalline: when heated, indigo-blue sublimes, and the residuary alumina possesses a greenish tint. Compounds of indigo-white with metallic oxides are best procured by adding the crystalline salts of the latter to saturated alkaline solutions of the former, in entirely filled and well-stoppered bottles. According to **Löwig**, the lead compound obtained in this way is somewhat crystalline, deflagrates slightly when heated, and leaves metallic lead. The combination with tin gives a sublimate of indigo-blue. The precipitates with manganese and cobalt are green, and afford no sublimate.

The action of sulphuric acid on indigo-blue gives rise to a number of beautiful and highly interesting bodies. First among these stands *hyposulphoindigotic acid*, synonymous with *sulphindigotic acid*, and with the *sulphindylic acid* of **Dumas**, which may be obtained by digesting, for three days, one part of indigo-blue with fifteen of concentrated sulphuric acid in a stoppled bottle, and at a temperature not lower than 120°, but which should not be allowed to exceed 140°. A deep blue solution, without any evolution of sulphurous acid, results; this is perfectly miscible with water, and if the proportions above-mentioned have been maintained in the manipulation, there is no sediment. When evaporated, the acid remains as a dark-blue substance, deliquescent, and possessed of a singular odor; with water and alcohol it gives an intense blue solution, having a sour and slightly astringent taste. Woollen cloth steeped in the diluted menstruum abstracts the color, becoming effectually dyed. By macerating the wool, after this treatment, in a solution of carbonate of ammonia, hyposulphoindigotate of ammonia is obtained, whence other salts of the colored acid may be procured. For the preparation of the potassa compound, **Dumas** gives the following recipe:—

A strong solution of acetate of potassa is poured into an aqueous one of the concentrated blue liquor, which occasions a deposit of sulphate and sulphoindigotate of the alkali; the whole is filtered through pure bibulous paper placed upon a remnant of linen cloth, and percolation allowed to proceed for twenty-four hours; the filtrate ought to be perfectly clear and almost devoid of color. The subsidence is then collected, agitated in a concentrated solution of acetate of potassa, and the filtration repeated; the sulphate is thus separated from the blue compound, but as a portion of the former still remains in admixture, the precipitate is again thoroughly diffused in acetate of potassa, and the whole is replaced on the strainer. The acetate is now removed by edulcoration with alcohol, and, finally, the salt is desiccated *in vacuo*. The formula generally accepted for sulphoindigotic acid is $H O, C_{16} H_4 O_2 N + S_2 O_5$; that assigned to its potassa compound being $K O, C_{16} H_4 O_2 N, S_2 O_5$, in which the indigo is dispossessed of one atom of hydrogen, while the two equivalents of sulphuric acid have lost one of oxygen. **Dumas**, however, gives it the formula of a double sulphate, $C_{16} H_4 O N, S O_3 + K O, S O_3$, and institutes an analogy between alcohol and indigo-blue; thus, the latter being represented as $H O, C_{16} H_4 O N$, the body $C_{16} H_4 O N$ would be the counterpart of oxide of ethyl. His views, however, are far-fetched, are not supported by the chemical relations of the substances in question, and, moreover, are less obvious and convenient than those previously given.

Zinc or iron deprives an aqueous solution of hyposulphoindigotic acid of its color, without causing any hydrogen to be evolved; the usual hue returns, however, on withdrawal of the metal and exposure to the air. It is not altered in any way by sulphide of hydrogen at ordinary temperatures, but when heated to 120° the color disappears, and a deposit of sulphur occurs. All the substances which reduce indigo-blue to indigo-white, have a corresponding action on this acid.

Salts of hyposulphoindigotic acid are most advantageously procured by direct saturation; by transmitted light they are generally of a red color. When protosulphate of iron is dissolved in a solution of a neutral hyposulphoindigotate, the tinge is not altered, nor is it affected when part of the oxide is thrown down by alkali, but when it is entirely precipitated, and especially when a slight quantity of alkali has been added in excess, decoloration immediately takes place. The blue again reverts on saturating with an acid. Common sulphates and the generality of salts cause deposits in solutions of hyposulphoindigotates of alkali, which are only sparingly soluble in alcohol. If the blue acid be slightly supersaturated with carbonate of potassa, the mixture assumes a gelatinous aspect; the same effect is secured by adding sulphate and the other salts of potassa —with the exception of the nitrate—to a mixture of hyposulphoindigotic with sulphuric acid; the resulting subsidence when desiccated shrinks, and acquires a cupreous hue. Boiling water dissolves the potassa salt, but deposits the greater portion of it on cooling: the ammonia and soda compounds bear a great similarity to that of potassa. Water, when cold, with difficulty dissolves the hyposulphoindigotates of lime and of baryta, but, when hot, forms with them blue menstrua, which throw down the greater part of the salts on cooling.

When one part of indigo is dissolved in eight parts of oil of vitriol, the addition of water separates a purple powder. The filtrate from this contains, according to Berzelius, sulphoindigotic and hyposulphoindigotic acid, while the deposit just mentioned forms a third—*sulphopurpuric*, the *phenicin* of Crum. This must be immediately edulcorated with water to which a little hydrochloric acid has been added, till every trace of free sulphuric acid has disappeared, and then cautiously exsiccated. Dumas recommends drying it in an oil bath, between the temperatures of 356° and 392°. If the heat is not carried beyond the former degree, moisture is retained, while at the latter decomposition commences.

Sulphopurpuric acid readily dissolves in water and in alcohol. If digested in sulphuric acid, it is converted into hyposulphoindigotic acid. According to the last-named chemist, it is composed of two equivalents of indigo-blue and two of sulphuric acid, which together unite with one atom of base. Its centesimal constitution, when anhydrous, is as under:—

	At. weight.	Theory.	Dumas.
32 Eqs. Carbon,...........	192 ..	56·14 ..	56·5
10 Eqs. Hydrogen,...........	10 ..	2·93 ..	2·9
4 Eqs. Oxygen,.............	32 ..	9·35 ..	7·4
2 Eqs. Nitrogen,...........	28 ..	8·19 ..	8·1
2 Eqs. Sulphuric acid,......	80 ..	23·39 ..	23·1
1 Eq. Sulphopurpuric acid,..	342	100·00	100·0

Salts of sulphopurpuric acid may be prepared by adding its aqueous solution to that of any salt; the acid of the latter is liberated, and the sulphopurpurate of the base deposited. In general, the appearance of the salts resembles that of the acid: they vary in solubility, according to the bases employed, those of soda and ammonia being most readily liquefied. The compounds of sulphopurpuric acid with lime, magnesia, protoxide of iron, and oxides of copper and zinc, are so far insoluble as to communicate to water a pale-blue tinge only. They dissolve better in alcohol than in water, and have, in common with indigo-blue, the attribute of being decolored by deoxidising agents, and re-acquiring color on exposure to atmospheric influence.

The whole subject of the compounds of indigo with acids is still exceedingly obscure, and must continue so till additional researches shall have been vigorously and faithfully executed.

Notwithstanding, however, the number and intricacy of the bodies produced by the action of sulphuric acid on this composite dye-stuff—which, at the same time, are highly interesting—the principles afforded by its oxidation are still more numerous, and full as many difficulties have hitherto attended, and still seem likely to accompany, the investigations into their composition and various properties.

Isatin is one of the products obtained when indigo is oxidised by means of chromic or nitric acid. It seems to have been simultaneously discovered by Erdmann and by Laurent.

To procure it, indigo, mixed with water to the consistence of a thin paste, is gently warmed, and nitric acid added in small quantities—allowing the effervescence caused by each addition to cease before adding the next portion—till the blue color is destroyed, avoiding, however, the presence of more acid than is necessary for this purpose. A brown deposit is afforded. The mass is now boiled with a large quantity of water, and the filtrate on cooling deposits isatin in crystals. These are purified by dissolving them in potassa, and adding hydrochloric acid as long as it causes a black or brown subsidence of resinous matter. When a filtered portion gives, with hydrochloric acid, a pure bright-red precipitate, the whole is passed through bibulous paper and mixed with the acid, which causes the isatin to fall in crystals. This is to be well washed with cold water, and crystallized from a hot alcoholic solution.

When chromic acid is employed, its dilute aqueous solution is gradually added to pulverised indigo; the mixture is heated nearly to its boiling point, and a brown liquid is obtained. The chromic acid should only be of such strength as freely to dissolve the indigo; for, if it be too strong, carbonic acid is evolved, oxide of chromium is precipitated, and isatin is not formed. The brown menstruum should be filtered whilst hot, and the isatin crystallizes on cooling.

Isatin, thus prepared, forms brilliant hyacinth-red or reddish-brown prismatic crystals which are inodorous, dissolving scantily in cold, but more abundantly in hot water; readily soluble in alcohol, but less so in ether. The alcoholic menstruum imparts a peculiarly disagreeable and permanent odor to the cuticle. When isatin is subjected to heat in a tube, a portion of it sublimes, but the greater part undergoes decomposition, and a difficultly combustible charcoal remains. When heated in the air, fusion takes place, a suffocating odor is exhaled, a brilliant flame appears, and a considerable amount of carbonaceous matter is left. Isatin dissolves in solutions of potassa and of ammonia, as also in those of sulphides of hydrogen and ammonium, giving rise to a host of compounds of peculiar character, but with too little promise of utility in the arts to warrant their special enumeration.

The centesimal composition of isatin is—

	At weight.	Theory.	Laurent.	Erdmann.
16 Eqs. Carbon,......	96 ..	65·30 ..	65·2 ..	65·3
5 Eqs. Hydrogen,....	5 ..	3·40 ..	3·5 ..	3·4
4 Eqs. Oxygen,......	32 ..	21·77 ..	21·8	31·3
1 Eq. Nitrogen,....	14 ..	9·53 ..	9·5	
1 Eq. Isatin,........	147	100·00	100·0	100·0

Isatin is, therefore, indigo plus two equivalents of oxygen, or $C_{16}\,H_5\,O_2\,N + O_2 = C_{16}\,H_5\,O_4\,N$.

The purple menstruum which isatin forms with caustic potassa becomes yellow when heated, and furnishes, on evaporation, a crystalline salt, in small hard prisms—isatinate of potassa. When this is dissolved, and acetate of lead added, a white precipitate falls, which, diffused through water and decomposed by sulphide of hydrogen, yields a colorless acid solution: this, if allowed to evaporate spontaneously *in vacuo*, leaves a white and scarcely crystalline powder, which is *hydrated isatinic* acid. If boiled in water, it is resolved into water and isatin, which is deposited, on the cooling of the menstruum, in a crystalline state, the latter having acquired a brown color. Most of the isatinates are insoluble, or only dissolve with difficulty in water, and may be procured, as just described, by the double decomposition of the potassa salt. Anhydrous isatinate of silver is composed of—

		Centesimally.		
	At. weight.	Theory.	Erdmann.	Laurent.
16 Eqs. Carbon,	96	35·29	35·18	35·22
6 Eqs. Hydrogen,	6	2·20	2·03	2·48
5 Eqs. Oxygen,	40	14·71	22·51	62·30
1 Eq. Nitrogen,	14	5·15		
1 Eq. Oxide of silver,	116	42·65	40·28	
1 Eq. Isatinate of silver,	272	100·00	100·00	100·00

Laurent gives the formula of crystallized isatinate of silver, procured by mixing solutions of nitrate of silver and isatinate of potassa in a state of ebullition, as $AgO, C_{16}H_6O_6N, HO$.

According to **Erdmann**, when isatin is dissolved in sulphide of ammonium by means of heat, there is deposited on cooling a yellowish-white powder, *not crystalline*, which he terms *isatyd*. **Laurent** obtained it previous to the year 1844, by adding a little sulphide of ammonium to a hot alcoholic solution of isatin, and allowing the mixture to rest in a stoppered phial; small white crystals soon formed, and in the course of eight days a grey deposit occurred: this was separated, washed with alcohol, and was found on microscopical examination to consist of minute prismatic and octohedral crystals; the latter were sulphur, and were removed by sulphide of carbon, in which they are soluble, while those of isatyd are found not to possess this characteristic.

More lately, the same chemist has devised an ingenious way of isolating it:—Pulverised isatin is heated in a flask, with a large quantity of water, a little sulphuric acid, and a fragment of pure zinc. The isatin gradually dissolves, seizing the nascent hydrogen, and being transformed into isatyd, which is precipitated as a crystalline powder. This is then separated, washed with and dissolved in alcohol, from which it is permitted to crystallize.

Isatyd is insoluble in water, and only sparingly dissolves in boiling alcohol and ether, which deposit it in microscopic crystals on cooling. It dissolves in alkalies with a dark-red color, which, on the application of heat, changes to yellow. The solution in potassa, according to **Erdmann**, deposits crystals, and gives, when treated with hydrochloric acid, a flocculent yellow precipitate.

Its analysis gave the following results, showing it to be isatin plus one equivalent of hydrogen, and bearing the same relation to isatin as indigo-white to indigo-blue.

		Contesimally represented.	
	At. weight.	Theory.	Laurent.
16 Eqs. Carbon,	96	64·86	65·11
6 Eqs. Hydrogen,	6	4·06	4·13
4 Eqs. Oxygen,	32	21·62	21·26
1 Eq. Nitrogen,	14	9·46	9·50
1 Eq. Isatyd,	148	100·00	100·00

When chlorine is passed through a solution of isatin, or through water in which indigo is held in suspension, two new substitution compounds are formed, which were termed by **Laurent**, in accordance with his nomenclatural rules, *chlorisatinase* and *chlorisatinese;* **Erdmann**, however, more consistently with the methods of designation now generally adopted, gave them the appellations, *chlorisatin* and *bichlorisatin*, which are quite as explanatory. If, when the action of the chlorine on the indigo and water has been carried to the fullest extent, the crude product be distilled, volatile substances and water pass over, the former crystallizing in the neck of the retort and in the receiver, a mixture of chlorisatin and bichlorisatin remaining. These may be separated by means of alcohol in a state of ebullition; the chlorisatin, being more insoluble than the accompanying principle, deposits on cooling. By repeating the solutions in, and crystallizations from alcohol, they may be very effectively disunited and purified.

Chlorisatin, $C_{16}\left\{\begin{matrix}H\\Cl\end{matrix}\right. O_4N$, forms transparent orange-yellow four-sided prisms, isomorphous with isatin, and in all respects very analogous to it. One hundred parts of alcohol, of 0·830 specific gravity, dissolve 0·45 of chlorisatin, forming a dark orange-colored menstruum, neither acid nor alkaline, and which communicates to the skin a disagreeable and adherent odor. Chlorisatin is inodorous, bitter, almost insoluble in cold, but abundantly dissolving in hot water. It bears a heat of 320° without undergoing decomposition; at temperatures more elevated, fumes similar to those of burning indigo are evolved, and it ignites.

If dissolved in warm aqua potassæ, crystals of *chlorisatinate* of the alkali form, the chlorisatin by combination with one atom of water having been converted into *chlorisatinic acid*, thus:—

$$\underbrace{C_{16}\left\{\begin{matrix}H_4\\Cl\end{matrix}\right. O_4\,N}_{\text{Chlorisatin.}} + \underbrace{H\,O}_{\text{Water.}} = \underbrace{C_{16}\left.\begin{matrix}\\\end{matrix}\right\}\begin{matrix}H_5\\Cl\end{matrix} O_5\,N}_{\text{Chlorisatinic acid.}}$$

The principle, *bichlorisatin*, remains in the alcoholic menstruum after the deposition of chlorisatin, than which it is more soluble, and consequently not so crystallizable. When its purification has been effected by redissolving in, and crystallizing from alcohol, it forms brilliant pink needles. With weak solution of potassa, it forms, at first, a deep-red liquid, which, on the application of heat, changes to yellow, and yields crystalline scales of that color, composed of the alkaline base and bichlorisatinic acid.

The formula of bichlorisatin is $C_{16}\left\{\begin{matrix}H_3\\Cl_2\end{matrix}\right. O_4\,N$, and in the change just noticed, it—like chlorisatin—unites with water, and the formula of the resulting acid is, according to **Laurent**, $C_{16}\left\{\begin{matrix}H_4\\Cl_2\end{matrix}\right. O_5\,N$. The acid may be separated from the potassa salt by stronger acids, as a yellow powder, which, when dissolved and warmed, is resolved into bichlorisatin and water.

Bromine acts on isatin, and forms two bodies, *bromisatin* and *bibromisatin,* in every respect analogous with the bodies resulting from the action of chlorine on isatin; the formulæ are as follow :—

Bromisatin, ... $C_{16}\left\{\begin{matrix}H_4\\Br\end{matrix}\right. O_4\,N$
Bromisatinic acid, ... $C_{16}\left\{\begin{matrix}H_5\\Br\end{matrix}\right. O_5\,N$
Bibromisatin,.................... $C_{16}\left\{\begin{matrix}H_3\\Br_2\end{matrix}\right. O_4\,N$
Bibromisatinic acid, ... $C_{16}\left\{\begin{matrix}H_4\\Br_2\end{matrix}\right. O_5\,N$

Isatin, and its substitution compounds, chlorisatin, bromisatin, bichlorisatin, and bibromisatin, form, with sulphites, salts composed of one equivalent of the base, one of the principles derived from indigo, and two atoms of sulphurous acid, having names and formulæ as under, the symbol MO representing the metallic oxide :—

Isatino-sulphites, ... $MO,\ C_{16}\,H_5\,O_4\,N,\ 2\,S\,O_2$
Chlorisatino-sulphites, ... $MO,\ C_{16}\left\{\begin{matrix}H_4\\Cl\end{matrix}\right. O_4\,N,\ 2\,S\,O_2$
Bromisatino-sulphites, ... $MO,\ C_{16}\left\{\begin{matrix}H_4\\Br\end{matrix}\right. O_4\,N,\ 2\,S\,O_2$
Bichlorisatino-sulphites, .. $MO,\ C_{16}\left\{\begin{matrix}H_3\\Cl_2\end{matrix}\right. O_4\,N,\ 2\,S\,O_2$
Bibromisatino-sulphites, .. $MO,\ C_{16}\left\{\begin{matrix}H_3\\Br_2\end{matrix}\right. O_4\,N,\ 2\,S\,O_2$

The long-continued action of dilute nitric acid upon indigo, occasions the formation of *indigotic,* sometimes termed *anilic acid,* and identical with *nitro-salicylic* or *nitro-spiroylic acid.* Fourcroy and Vauquelin, its discoverers, considered it to be benzoic acid. Its composition was subsequently ascertained by Buff and by Dumas. It was obtained by the action of nitric acid on spiroylic acid by Marchand, and Gerhardt procured it by the same process from salicin. It may be isolated by the following method :—Introduce into a tubulated retort, two parts of nitric acid having a specific gravity of 1·28, which has been previously diluted with an equal weight of water, and gradually add one part of coarsely-pounded indigo; adapt a receiver, and apply heat gently to the retort by means of a sand-bath; violent action will occur, and may require the removal of the heat from the apparatus. When quiescence has ensued, and the retort has cooled, resinous matter and crystals of indigotic acid will be found floating upon the surface of the menstruum. These must be separated and treated with water, which will dissolve the indigotic acid, the solution of which must be returned to the acid liquor in the retort, and the mixture so concentrated that crystallization will occur on cooling. The residue will deposit crystals of indigotic and nitropicric acid, which are to be redissolved in boiling water, the indigotic acid separating on cooling, while the nitropicric acid remains in solution.

The purification of indigotic acid from resinous and other impurities may be effected by dissolving the crystals—obtained by the process just described—in boiling water, and adding recently-prepared carbonate of lead to saturation; the liquor is then filtered as speedily as possible, and on cooling, *indigotate of lead* is deposited. This is dissolved in water in a state of ebullition, decomposed by dilute sulphuric acid, and the whole filtered while hot: on the filtrate being reduced in temperature, slender prisms of indigotic acid will form, yellow under the influence of adhering moisture, but nearly white when dry. If it is desirable to obtain the crystals perfectly colorless, it is merely requisite to employ dilute nitric instead of sulphuric acid, for decomposing the indigotate of lead.

The crystals formed in the aqueous solution of indigotic acid possess four equivalents of water. On desiccating them at a temperature between 300° and 450°, three atoms are expelled, and their formula is then $H\,O,\ C_{14}\,H_4\,O_5\,N\,O_4$, or $H\,O,\ C_{14}\,H_4\,O_9\,N$. Its composition in this state is represented underneath, that analysed by Marchand being obtained by the action of nitric upon salicylic acid; that employed in the examination of Cahours was procured from the oil of the *Gaultheria procumbens,* while the specimen of which Dumas ascertained the relative constituents was derived from indigo.—

		Centesimally represented.			
	At. weight.	Theory.	Marchand.	Cahours.	Dumas.
14 Eqs. Carbon,.....	84	45·90	45·78	45·55	45·9
5 Eqs. Hydrogen, ..	5	2·73	2·76	2·98	3·0
10 Eqs. Oxygen, ...	80	43·72	43·77	43·78	43·3
1 Eq. Nitrogen,....	14	7·65	7·69	7·69	7·8
1 Eq. Indigotic acid,	183	100·00	100·00	100·00	100·0

When cautiously subjected to an elevated temperature, it volatilizes without decomposition, and condenses in white needles. Boiling water dissolves it in almost any proportion, but of the same menstruum at 50°, it requires for solution one thousand parts.

Its salts nearly all possess a yellowish hue and a nauseous taste, and, when heated, deflagrate. The acid gives with the salts of sesquioxide of iron a deep-red color; it has no influence on the protosalts, and does not cause a subsidence in gelatinous menstrua.

Nitropicric acid—mentioned above as being retained in solution in the preparation of indigotic acid—was, according to Brande, first noticed in the year 1788 by Hausman. It was subsequently obtained by the action of nitric acid upon silk by Welter, and bore, for a protracted period, the appellation of *Welter's bitter principle;* its acid properties were first described by Chevreul; the next examination was performed by Liebig, and Dumas has since completed a more exact investigation of it.

Liebig prepares the acid in the following manner :—A portion of the best indigo, broken into small fragments, is gently heated with eight or ten times its weight of nitric acid of moderate strength. Solution occurs, an abundance of nitrous vapor is evolved, and the mass swells. After the scum has fallen, the liquid is boiled, and nitric acid added as long as any disengagement of red fumes is occasioned. When the liquid has become cold, semi-transparent yellow crystals form in large quantity, and, if the operation has been well conducted, no artificial tannin or resin is present. The crystals are edulcorated with cold water, and then boiled in water sufficient to dissolve them. If any globules of tannin form on the surface of the menstruum, they must be carefully removed by touching them with bibulous paper. Then, filtering the fluid and allowing it to cool, yellow brilliant crystalline plates will be obtained, which will not lose their lustre by washing. To procure the substance perfectly pure, the crystals must be redissolved in boiling water, and neutralized by carbonate of potassa. Upon cooling, the potassa salt crystallizes, and should be purified by repeated crystallizations. On mixing the first mother-liquor with water, a considerable brown precipitate is obtained, which, being dissolved in boiling water, and neutralized by carbonate of potassa, also affords a quantity of the alkaline compound. All the potassa salt obtained in these operations is redissolved in boiling water, and nitric or hydrochloric acid added; as the solution cools, the nitropicric acid will be observed to form very brilliant plates of a clear yellow color, generally in equilateral triangular forms. Sometimes crystals are not formed after the action of nitric acid on the indigo, in which case the liquor must be evaporated and water added, when the acid will precipitate, and purification may be effected as already recited. Four parts of indigo yield one of this acid.

When nitropicric acid is subjected to heat, it liquefies, and is volatilized without decomposition; when suddenly exposed to a strong heat, it inflames without explosion, its vapors burning with a yellow flame, and a carbonaceous residue remaining. It is only slightly soluble in cold, but much more in boiling water. The aqueous menstruum has a bright-yellow color, and an extremely bitter taste, reddens litmus, and acts like a strong acid on metallic oxides, dissolving them and giving rise to peculiar crystalline salts. Ether and alcohol dissolve it readily. When fused in chlorine or with iodine, it is not decomposed, nor does chlorine water affect it. Cold sulphuric acid leaves it intact; when hot, it dissolves it, but water separates it again without alteration. Boiling hydrochloric acid does not affect it, and nitro-hydrochloric acid only with great difficulty.

Most chemical authors, says **Blumenau**, state that nitropicric acid is not decomposed by nitric acid; but this is an error, and under certain conditions it is resolved into nitric oxide, oxalic acid, and perhaps also carbonic acid. In the experiments performed by him to ascertain this point, the nitropicric acid was prepared by placing three pounds of the best indigo in thirty-five pounds of nitric acid just at the point of ebullition; as the violent action subsided, the whole was removed into a retort. A considerable quantity of the—so called—resin had formed, but the liquid, on cooling, furnished abundance of crystals. In order to destroy the resin, the contents of the retort were for seven days kept simmering ten hours *per diem.* Red vapors were constantly evolved, all but a mere trace of the resin had disappeared, and the inspissated liquids now furnished very few crystals of nitropicric acid; instead of weighing twelve ounces, they were only twelve drachms. The whole operation was most strictly watched and carefully conducted. The author, therefore, was compelled to attribute the loss of nitropicric acid to its decomposition by the nitric acid. In a later investigation, when heat was applied only for a very short time, the produce always amounted to one-fourth of the indigo employed, thus proving that a decomposition of the nitropicric acid must have occurred in the former operation. According to the last-mentioned chemist, the form of the crystals of nitropicric acid is very variable. Those obtained from boiling water were of a lemon or canary color, laminated and opaque, but by exposure to warm air becoming transparent and of a yellowish-brown tinge. The crystallized acid obtained from alcohol had the same form, transparency, and hue. From ether the acid crystallized on slow evaporation in beautiful yellowish-brown transparent crystals, having a faint glassy lustre, and in the form described by **Mitscherlich**: after long exposure to the air these had the color of the thin laminæ which were obtained from hot water; by subjecting them to the action of the atmosphere, they were again rendered transparent.

The formula usually assigned to nitropicric acid is,

$$HO, C_{12} \left\{ \begin{matrix} H_2 \\ 3\,NO_4 \end{matrix} \right. O.$$

It has been analysed with the following results:—

		Centesimally represented.				
	At. weight.	Theory	Marchand.	Schunck.	Dumas.	Laurent.
12 Eqs. Carbon, ...	72	31·45	31·43	31·97	31·8	31·86
3 Eqs. Hydrogen,...	3	1·31	1·36	1·36	1·4	1·52
14 Eqs. Oxygen, ...	112	48·91	48·72	48·16	48·3	48·00
3 Eqs. Nitrogen,...	42	18·33	18·49	18·51	18·5	18·62
1 Eq. Crystallized Nitropicric acid,	229	100·00	100·00	100·00	100·0	100·00

All the salts of nitropicric acid readily crystallize, and, when subjected to heat, explode with more or less violence. When they are placed in contact with lime and sulphate of iron, blood-red solutions are formed, containing a new acid in combination with lime.

Another very extensive series of entirely distinct compounds originates from the action of the alkalies upon indigo. A concentrated boiling solution of caustic potassa, having a specific gravity of 1·45, dissolves indigo rapidly, and the menstruum assumes a brown color; on evaporation, brilliant crystals begin to appear, and, when cool, a concrete mass remains, which affords with water a brown, and with alcohol a deep-green solution. The former is similar to the alkaline solution of indigo-white, noticed at page 593, and very quickly becomes coated with a beautiful iridescent and partly crystalline scum of indigo-blue. On nearly neutralizing the potassa by a mineral acid, a blue-green precipitate is formed, and a golden-yellow liquor is obtained on filtration, which, on being supersaturated with acetic acid, gives a voluminous brown flocculent deposit, containing, according to **Fritzsche**, a new body, termed by him *chrysanilic acid.* To separate it, the subsidence is agitated with its bulk of ether; a golden-yellow menstruum results, which, when evaporated, leaves the acid as a reddish-yellow substance. When thrown down from its alkaline solution by an acid, and exsiccated, it has the color of kermes. Its solution in the alkalies is yellow, and on adding an excess of the solvent a green tinge appears, and it becomes covered with a pellicle of the same hue, which, under the microscope, seems to be somewhat crystalline. When subjected to ebullition in the dilute mineral acids, it affords a red liquid, which, on cooling, deposits bluish-black acicular crystals, and *anthranilic acid* remains dissolved in the menstruum. The composition of chrysanilic acid is extremely uncertain. **Fritzsche** has, however, assigned to it the formula $HO, C_{28} H_{10} O_5 N_2$.

To prepare anthranilic acid, indigo-blue is kept boiling in a solution of caustic potassa—specific gravity 1·35 —a little water being occasionally added as the liquor acquires a thicker consistence. Previous to the disappearance of the last remains of the indigo, finely pulverised binoxide of manganese is added to the boiling menstruum, till a sample of it, on dilution with water, no longer deposits indigo-blue; if it then be heated with an excess of acid, it only yields a slight brown precipitate, and retains in solution *anthranilate of potassa*, and a considerable amount of caustic alkali. In this state it is to be diluted with water in a state of ebullition, supersaturated by dilute sulphuric acid, and filtered. The filtrate is then neutralized with potassa, and evaporated to dryness. The residue consists of sulphate and anthranilate of the alkali, and a brown coloring matter; the latter two are abstracted by hot alcohol, which leaves the sulphate of potassa. On distilling off the spirit, dissolving the remainder in water, and supersaturating by acetic acid, orange-colored crystals of impure anthranilic acid are deposited; these are now combined with lime, the resulting anthranilate of that earth dissolved in hot water, and the solution decomposed by acetic acid: on cooling, the hydrated anthranilic acid forms transparent yellow foliated crystals, terminating dihedrally. A saturated solution of the salt of lime, decomposed by acetic acid, deposits acicular crystals of anthranilic acid, which are white, and possess a very bitter taste.

According to LIEBIG, anthranilic acid dissolves sparingly in cold water, but is readily soluble in alcohol and ether, and these solutions have the taste of benzoic acid, and give an acid reaction. It has been analysed with the following results:—

		Centesimally represented.		
	At. weight	Theory.	Fritsche.	Liebig.
14 Eqs. Carbon,..................	84	61·31	61·82	62·13
7 Eqs. Hydrogen,..............	7	5·11	5·09	5·16
4 Eqs. Oxygen,................	32	23·36	22·25	32·71
1 Eq. Nitrogen,..............	14	10·22	10·84	
1 Eq. Crystallized anthranilic acid,	137	100·00	100·00	100·00

In the year 1841, a communication was made to the Academy of Sciences at Paris, from which it appeared that GERHARDT, on treating indigo with hydrate of potassa, produced valerianic acid. The prescribed method was as follows:—

Indigo, cut into small pieces, is to be placed in fused hydrate of potassa, in which it dissolves, becoming yellow, and largely disengaging ammonia and hydrogen. On fusion, a mixture of valerianate and carbonate of potassa is obtained, from which, by distilling it with dilute sulphuric acid, valerianic acid is separated. GERHARDT expressed the transformation in the following equation:—

$$\underbrace{C_{16} H_5 O_2 N}_{\text{Indigo.}} + \underbrace{14 H O}_{\text{Water.}} = \underbrace{HO, C_{10} H_9 O_3}_{\text{Hydrated valerianic acid.}} + \underbrace{6 C O_2}_{\text{Carbonic acid.}} + \underbrace{N H_3}_{\text{Gaseous ammonia}} + \underbrace{6 H}_{\text{Hydrogen.}}$$

The carbon of the indigo is thus divided, and forming partly valerianic, and partly carbonic acid, it combines with the potassa. The carbonic acid is formed at the expense of the water, three equivalents of the hydrogen of which, uniting with the nitrogen, produce gaseous ammonia, while the remainder of the same gas escapes in the reaction. This transformation, however, which in the above equation seems so easily developed, did not proceed with the same facility, under other hands, in the crucible; WINKLER and ERDMANN alike repeated the experiments of GERHARDT, but unsuccessfully.

To bring this matter to a decision, the Editor repeated the process, and made a full examination of the acid thus formed.

The attentive consideration of the action of potassa on indigo, causes, *from theoretical reasons alone*, the formation of valerianic acid to appear in the highest degree problematical.

In the Editor's investigation, the action of potassa on pure indigo was first studied. Indigo-blue was heated in a silver capsule with hydrate of potassa, until a portion, on treatment with water and acids, gave evidence that the whole of the coloring matter was decomposed. A trifling excess of sulphuric acid was now added, which caused a vivid effervescence, and the evolution of a peculiar odor. The whole being filtered, and the filtrate distilled, a clear liquid, possessing the same singular smell, and giving an acid reaction, was obtained, and from which a baryta compound was formed. This afforded indubitable proofs of the presence of acetic acid.

A larger quantity of indigo was now treated in the same manner, but the baryta compound was also distilled with concentrated phosphoric acid. The distillate gave an intense acid reaction, and possessed the odor of acetic acid. The analysis of the baryta and silver salts, the evolution of acetic ether on the ebullition of the baryta compound with alcohol and strong sulphuric acid, as well as the respective reactions with arsenious acid, nitrate of mercury and other tests, gave infallible evidence that the so-called valerianic acid was acetic acid, and that only.

The acetic acid seems to be formed from foreign substances which are accidentally mixed with the indigo-blue. Reduced indigo—which was not, however, absolutely pure—gave a much smaller amount of the acid than the indigo of commerce. The valerianic acid obtained by GERHARDT—if it was obtained, and the statement, from such an eminent chemist, scarcely admits of doubt—must have been derived from foreign matter present in the indigo he employed.

When anthranilic acid is mixed with pulverised glass, and heated rapidly, it is resolved into carbonic acid and *anilin*, a powerful base, devoid of oxygen.

$$\underbrace{C_{14} H_7 O_4 N}_{\text{Anthranilic acid.}} = \underbrace{2 C O_2}_{\text{Carbonic acid.}} + \underbrace{C_{12} H_7 N.}_{\text{Anilin.}}$$

It was formerly denominated *crystallin*, from its great tendency to form crystallizable salts with acids, and when obtained from coal tar, it is frequently termed *cyanol* or *kyanol*. It seems first to have been noticed by UNVERDORBEN, in the empyreumatic oil obtained when distilling bone and other animal substances. RUNGE then obtained it as one of the products of the distillation of coal tar. It was procured on the distillation of anthranilic acid by **Fritzsche**, and **Zinin** produced it by the action of sulphide of hydrogen upon *nitrobenzid*. He termed it *benzidam*, representing it as an *amide of benzin*, $C_{12}\ H_5 + N\ H_2$; this appellation was subsequently changed to *benzidin*, but Dr. A. W. **Hofmann** has more recently proved it to be identical with anilin, shown cases of its formation from other bodies, and added much to the knowledge of its properties, as well as those of its compounds. As has been mentioned above, anilin may be obtained by heating anthranilic acid with powdered glass, but it is more advantageously procured by the dry distillation of an alkaline salt of anthranilic acid, or indigo may be added to a hot solution of caustic potassa, and the resulting compound at once distilled. The product from either of these methods of manipulation is impure, but all the foreign matters may be removed by distilling it off potassa in an atmosphere of carbonic acid.

But **Hofmann** has shown that the most eligible mode of isolating it is to heat isatin with hydrate of potassa, carbonate of the alkali being also formed, and hydrogen evolved.

$$\underbrace{C_{16}\ H_5\ O_4\ N}_{\text{Isatin}} + \underbrace{4\ (KO,\ HO)}_{\text{Hydrate of potassa.}} = \underbrace{C_{12}\ H_7\ N}_{\text{Anilin.}} + \underbrace{4\ (KO,\ CO_2)}_{\text{Carbonate of potassa.}} + \underbrace{H_2}_{\text{Hydrogen.}}$$

Anilin is a colorless, oily liquid, of very high refractive and dispersive power, having a potent disagreeable odor, and a hot aromatic flavor. According to **Hofmann**, its boiling point is 360°, but it is extremely volatile at ordinary temperatures, and the greasy mark which it occasions on paper speedily vanishes. Its specific gravity at 60° is 1·020. Cold water dissolves it to a certain extent, and the solution becomes turbid when subjected to heat. Alcohol, ether, and fat and volatile oils dissolve it in all proportions. With turmeric or reddened litmus paper, it affords no alkaline reaction, but it causes the violet hue of dahlia paper to turn green. White fumes appear when a glass rod, moistened with hydrochloric acid, is held over its aqueous solution. When aided by heat, anilin dissolves sulphur, but on cooling it is deposited in prismatic crystals: it also takes up phosphorus and camphor, but not copal or caoutchouc.

The following is its composition, **Fritzsche**'s analysis being performed on anilin procured from anthranilic acid; **Zinin** arrived at his results from the examination of *benzidin*—the product of the action of sulphide of hydrogen upon nitro-benzid—while the researches of **Hofmann** were conducted upon *cyanol*, or anilin obtained by the distillation of coal tar:—

		Centesimally represented.			
	At. weight.	Theory.	Fritzsche.	Zinin.	Hofmann.
12 Eqs. Carbon,	72	77·42	78·05	77·23	77·307
7 Eqs. Hydrogen,	7	7·53	7·60	7·50	7·720
1 Eq. Nitrogen,	14	15·05	14·98	14·84	14·973
1 Eq. Anilin,	93	100·00			100·000

Anilin neutralizes acids, forming salts which crystallize with remarkable facility, and which, on exposure to the atmosphere, absorb oxygen, acquiring a rose color, gradually passing into brown.

Anilin is readily recognised by its forming with chloroxide of calcium—bleaching powder—a compound of a beautiful but fugitive violet-blue color, which is generally regarded as a product of oxidation, but, according to **Fritzsche**, containing chlorine. Its composition has not yet been ascertained.

The addition of a few drops of nitric acid to anhydrous anilin gives rise to a fine blue color, which, on the application of a slight heat, passes into yellow, and a violent action results, sometimes followed by explosion; or, on the other hand, various changes of color are produced, and crystals of nitropicric acid are ultimately formed. On adding anilin to a solution of permanganate of potassa, binoxide of manganese is separated, and oxalic acid and ammonia are produced.

Various compounds are occasioned by the action of chlorine, bromine, nitric acid, cyanic acid, sulphide of carbon, and other substances, upon anilin, which, in a scientific point of view, are highly interesting, but are too numerous and complicated to warrant description. Many of those already noticed seem very unlikely to be of service in dyeing, and yet the same opinion was formerly held respecting the yellow salts produced by the combination of chromic acid with lead, while the advantage taken of this fact has completely revolutionized the tinctorial art.

Kermes.—*Kermes grains*, *alkermes*, are the dried bodies of the female insects of the species *Coccus ilicis*, which feed upon the leaves of the prickly oak—*Quercus ilex*. The word kermes is Arabic, and signifies little worm; in the middle ages this dye-stuff was, therefore, called *Vermiculus* in Latin, and *Vermillion* in French. It is curious to consider how the latter name has been since transferred to red sulphide of mercury.

Kermes has been known in the East since the days of **Moses**; it has been employed from time immemorial in India to dye silk; and was used also by the Greek and Roman dyers. **Pliny** designates it *Coccigranum*, and says that there grew upon the oak in Africa, Sicily, *et cetera*, a small excrescence like a bud, termed *Cusculium;* that the Spaniards paid with these grains half of their tribute to the Romans; that those produced in Sicily were the worst, those from the neighbourhood of Emerita in Lusitania the best, and that they were employed for dyeing purple.

In Germany, during the ninth, twelfth, thirteenth, and fourteenth centuries, the rural serfs were bound to deliver annually to the convents a certain quantity of kermes—the *Coccus polonicus*—among the other products of husbandry. It was collected from the trees upon Saint John's day, between eleven o'clock and noon, with religious ceremonies, and was therefore called *Johannisblut*—Saint John's blood—as also German cochineal. At the above period, a great deal of the German kermes was consumed in Venice for dyeing the scarlet to which that city gives its name. After the discovery of America, cochineal began to supersede kermes for all brilliant red colors.

The principal varieties of kermes are the *Coccus quercus*, the *C. polonicus*, the *C. fragariæ*, and the *C. uva ursi.*

The *Coccus quercus* insect lives in the South of Europe upon the kermes oak. The female has no wings, is of the size of a small pea, of a brownish-red color, and is covered with a whitish dust.

The kermes of Poland, or *Coccus polonicus*, is found upon the roots of the annual and perennial *scleranthus*, in sandy soils of that country, and the Ukraine, and has the same properties as the preceding.

Coccus fragariæ is found principally in Siberia upon the root of the common strawberry.

The *Coccus uva ursi* occurs in Russia, is twice the size of the Polish kermes, and dyes with alum a fine red.

When good, kermes is plump, of a deep-red color, having an agreeable smell, and a rough and pungent taste. Its tinctorial matter is soluble in water and alcohol; it becomes yellowish or brownish with acids, and violet or crimson with alkalies. Sulphate of iron blackens it. With alum it dyes a blood-red; with sulphate of iron, an agate-grey; with sulphate of copper and tartar, an olive-green; with tartar and a salt of tin, cinnamon-yellow. Scarlet and crimson dyed with kermes were called *grain colors*, which are accounted more durable than those of cochineal. The latter, however, and lac-dye, have now nearly superseded the application of kermes as a tinctorial substance in England.—*Ure.*

For a red, with tin, about twelve times the quantity of kermes as of cochineal is required, and the color is rather inferior. As a dye it is not much used, and only for silk or woollen. There seems to be no affinity between cotton and the tinctorial matters of *cochineal*, *lac*, and *kermes*.

LAC—*Laque*, French; *lack*, German—is a resinoid substance, the secretion of which appears to depend upon the puncture of a small insect—*Coccus ficus*—made for the purpose of depositing its ova upon the branches of several plants, especially the *Ficus religiosa* and *indica*, the *Rhamnus jujuba*, the *Croton lacciferum*, and the *Butea frondosa*, which grows in Assam, Siam, Pegu, Bengal, and Malabar. The twig soon becomes encrusted with a mammelated substance of a red color, more or less deep, nearly transparent, hard, and having a brilliant conchoidal fracture. The stick-lac of Siam is best, that of Assam ranks next, and, last, that of Bengal, in which the resinous coat is thin, scanty, and irregular. According to the analysis of Dr. JOHN, stick-lac consists, in one hundred and twenty parts, of—

An odorous common resin,	79·00
A resin insoluble in ether,	20·00
Coloring matter, analogous to that of cochineal,	4·50
Bitter balsamic matter,	3·00
Dun yellow extract,	0·50
Acid of the stick-lac—laccic acid,	0·75
Fatty matter, like wax,	3·00
Skins of the insects, and coloring matter,	2·50
Salts,	1·25
Earths,	0·75
Loss,	4·75
	120·00

According to **FRANKE**, the constituents of stick-lac are—resin, 65·7; substance of the lac, 28·3; coloring matter, 0·6. **UNVERDORBEN** distinguishes no less than five distinct resins, together with coloring and fatty matter, and a resinoid, to which **JOHN** gave the name of *laccin*. HATCHETT's results are as follow:—

	Centesimallv.
Resin,	68·0
Coloring matter,	10·0
Wax,	6·0
Gluten,	5.5
Foreign bodies,	6·5
Loss,	4·0
	100·0

When the resinous concretion is taken off the twigs, coarsely pounded, and triturated with water, the greater part of the tinctorial matter is dissolved, and the remaining granular portion dried in the sun, constitutes *seed-lac*. It contains less coloring matter than the stick-lac, and is much less soluble. HATCHETT found in it—

	Centesimally.
Resin,	88·5
Coloring matter,	2·5
Wax,	4·5
Gluten,	2·0
Loss,	2·5
	100·0

Shell-lac is made in India by putting the seed-lac into an oblong bag of cotton-cloth, which is held over a charcoal fire till the contents begin to melt, when the bag is twisted so as to strain the liquefied resin through its interstices, whence it is allowed to drop upon smooth stems of the banyan tree. In this way the resin spreads into thin plates, in which state it is found in commerce. The Pegu stick-lac, being very dark colored, furnishes a shell-lac of a corresponding deep hue, and therefore of inferior value. A stick-lac of an intermediate kind comes from the Mysore country, which yields a brilliant lac-dye, and a good shell-lac. HATCHETT analysed shell-lac, and found—

	Centesimally.
Resin,	90·9
Coloring matter,	0·5
Wax,	4·0
Gluten,	2·8
Loss,	1·8
	100·0

The tinctorial principle of lac is prepared in India by evaporating its aqueous infusion to dryness, and forming the residue into cakes of about two inches square, and half an inch in thickness. It is imported in two forms, called *lac-lake* and *lac-dye*, which contain about fifty per cent. of coloring matter, combined with more or less resin, and with earthy matters, consisting chiefly of carbonate and sulphate of lime, and silicic acid. According to Dr. URE, the cakes of *lac-dye* imported from India, impressed with peculiar marks to denote their various manufacturers, are now exclusively employed in England for dyeing scarlet cloth, and are found to give an equally bright color, and are not so much affected by perspiration, as that produced by cochineal. The solvent of the lac-dye is dilute sulphuric or hydrochloric acid; more particularly the latter, and the correct mordant is chloride of tin and tartar. The general characteristics of the coloring matter of lac seem very similar to those of cochineal and kermes, but it has not been the subject of any specific examination.

An excellent red is produced upon one pound weight of woollen by boiling for half an hour in water, to which has been added two ounces of lac, two of tartar, and four ounces by measure of *lac spirit*—perchloride of tin.

LOGWOOD.—*Bois de Campeche*, *Bois bleu*, French; *Blauholz*, German; *Hæmatoxylum*, Latin.—This wood is obtained in great abundance in Jamaica and on the eastern shores of the Bay of Campeachy, and is imported into this country in small pieces or blocks. The wood from the two localities produces different qualities of dye; on this account the name of its habitat is affixed to each, and the two kinds are distinguished in commerce as Campeachy and Jamaica logwood. The former is superior to the latter, and consequently fetches a higher price in the market. The logwood tree is called by botanists *Hæmatoxylum Campechianum*. In a favourable position it grows to a very large size. The bark of the tree is smooth and thin, and furnished with thorns, its leaves resembling those of the common laurel. The wood is very hard and close in the fibre, and is capable of taking on a fine polish, it is somewhat heavier than water, and consequently sinks when put into that liquid.

Logwood was introduced into this country as a dye early in the sixteenth century, and was in all probability first used by the dyers in these days, as it is still in some cases, to serve as an auxiliary in dyeing blues and blacks upon woollen, not only making the color more fugitive than had been previously the case with the use of woad, but seriously affecting the interests of the cultivators of the woad plant. These were, doubtless, the reasons of the absurd act passed by the government in the reign of Elizabeth, forbidding entirely the use of logwood under pains and penalties, as stated in the historical portion of this article—an act affording a striking proof of the gross impropriety of legislative interference with popular industry. This enactment had the natural effect of retarding the full development of the valuable dyeing properties of the wood. Nevertheless, they became gradually known; and when those interested in opposing the use of logwood found a much more serious intrusion upon their interests by the introduction of indigo, the restriction upon logwood was gradually relaxed, and then the virtues of this most useful dyewood began to be generally acknowledged. This was the natural result of experience, and perhaps there is no dye now so universally employed and so generally useful.

In the beginning of this century, the chemical properties of this tinctorial agent began to be studied by two French chemists, **CHEVREUL** and **ERDMANN**. The former, in a memoir published in 1811, furnished a process for separating the coloring matter, which he considers a distinct compound existing in the wood, and termed it *hæmatin*, a name which has since given place to *hæmatoxylin*, to avoid confounding it with a substance existing in the blood of animals, and which has been long known under the former designation. Besides this coloring matter, logwood also contains a fatty or resinous substance, volatile oil, a brown ingredient containing tannin, acetic acid, woody fibre, various salts, consisting generally of the phosphate, sulphate, and acetate of lime, acetate of potassa, and chloride of potassium; and sometimes the oxides of aluminium, silicium, manganese, and iron. These ingredients, however, vary, some woods having more than others, and others wanting some of them altogether; the differences of constitution being occasioned by the qualities of the soil on which the wood is matured.

According to **NAPIER**, the average ash left after incinerating several samples was 1·5 per cent., half of which was lime, with a trace of iron, the remainder consisting of magnesia, alumina, and silica.

The decoction of logwood, when newly made, is of a deep red, which is rendered paler but brighter colored by acids; alkaline substances give it a purplish or violet-blue hue; acetate of lead causes a slate-blue, alum a violet precipitate. The salts of iron make it dark violet-blue. When the infusion is exposed to the atmosphere it absorbs oxygen, becomes pale in color, and then acquires the property of precipitating gelatin, which it had not before.

CHEVREUL's process for procuring hæmatoxylin is to subject ground logwood to digestion for a few hours in water at 120° or 130°, afterwards filtering the liquor and evaporating to dryness; the residue is digested in strong alcohol for a day; this is again filtered, and the clear liquor boiled down till it becomes thick; to this is added a little water, and it is evaporated anew; it is then set aside, and the coloring matter crystallizes.

It is best obtained, says **ERDMANN**, by pulverizing the watery extract of the wood as prepared for pharmaceutical use, mixing it with a portion of sand to prevent agglutination, and digesting the mixture with six or eight times its volume of ether; it should be frequently shaken and poured off, and the greater part of the ether distilled from it; the residue is then mixed with water, and left to spontaneous evaporation in a lightly-covered basin. After some days the hæmatoxylin crystallizes, and may be washed with cold water, and pressed between folds of bibulous paper to free it from the mother-liquor. From two pounds of extract digested in two pounds of ether, this chemist obtained four ounces of hæmatoxylin.

Hæmatoxylin occurs in transparent brownish-yellow prismatic crystals, which afford a pale-yellow powder; they are efflorescent, and in a dry atmosphere lose the greater part of their water of crystallization. When rapidly heated to 212° they fuse, and then gradually become anhydrous. Hæmatoxylin has a sweet taste resembling that of liquorice root, without either bitterness or astringency; with alcohol and ether it produces reddish-yellow solutions. It is very sparingly soluble in cold water, but that menstruum readily dissolves it when boiling, and on cooling deposits it in crystals, which ordinarily contain eight equivalents of water of crystallization; but if a concentrated hot solution be allowed to cool in a well-closed vessel, it forms pale-yellow granular crystals, which only include three atoms of water.

The composition of hæmatoxylin, in its anhydrous state, is represented by the formula $C_{40}\ H_{17}\ O_{15}$.

		Centesimally	
	At weight.	Theory.	Erdmann.
40 Eqs. Carbon,..............	240	63·66	63·19
17 Eqs. Hydrogen,............	17	4·50	4·65
15 Eqs. Oxygen,..............	120	31·84	32·16
1 Eq. Anhydrous hæmatoxylin,	377	100·00	100·00

The ordinary crystals are $C_{40}\ H_{17}\ O_{15} + 8\ HO$, their ultimate elements being—

	At weight.	Theory.	Erdmann.
40 Eqs. Carbon,...............	240	53·46	53·78
25 Eqs. Hydrogen,..............	25	5·56	5·78
23 Eqs. Oxygen,...............	184	40·98	40·44
1 Eq. Crystallized hæmatoxylin,	449	100·00	100·00

When exposed to light, the crystals of hæmatoxylin gradually assume a reddish tint; their aqueous solution is reddened by nitric acid when very dilute, but if concentrated, effervescence is occasioned, and oxalic acid formed. Ammonia, either pure or carbonated, forms the most delicate test for hæmatoxylin, as under the influence of air it reddens the least trace of it. If air be carefully excluded, hæmatoxylin crystallizes unchanged from its ammoniacal solution, but when the atmosphere has access, the menstruum becomes purple: this, however, when acted on by sulphide of hydrogen, is bleached, and on evaporation yields colorless crystals of hæmatoxylin; but if it be continuously exposed, it gradually becomes opaque and of a deep cherry-red hue, and in this state acetic acid produces in it a bulky precipitate of the color of hydrated sesquioxide of iron. If the ammonia, as it volatilizes, be from time to time replaced, crystals are ultimately deposited of a compound of *hæmatéin* and ammonia. When hæmatoxylin is dissolved in a solution of potassa and carefully excluded from the atmosphere, no change occurs; but should air be admitted, oxygen is absorbed, and the color upon the sides of the vessel becomes first purple, and then brown. When baryta water is added to a solution of hæmatoxylin in water deprived of air, it causes a precipitate, white or pale-blue, quickly reverting to blue, red, and brown; carbonate of potassa produces the same effect, but less rapidly. The hydrated earths, and oxides of zinc, iron, copper, nickel, bismuth, and antimony, also precipitate hæmatoxylin, and the colors of these compounds, under the influence of air, are purple and blue. Chloride of barium gives a red, iron-alum a dark violet, and chloride of tin a rose-colored subsidence; alum occasions a red hue, with precipitation. When hydrated oxide of lead is introduced into a solution of hæmatoxylin, it becomes first blue, and then grey, in consequence of partial reduction. Acetate of lead yields a white deposit, soon substituted by blue. With salts of copper, the precipitates are at first greenish-grey, and then blue. Chlorides of mercury and platinum are not affected; that of gold is slowly, and nitrate of silver rapidly reduced.

Hæmatéin is formed by the action of air upon an ammoniacal solution of hæmatoxylin, as just noticed.

It may be procured in a pure state by mixing three hundred to three hundred and fifty grains of hæmatoxylin with as much aqueous ammonia as is requisite for its solution, exposing the compound to atmospheric action, and occasionally adding a little fresh ammonia, so as to maintain it in very slight excess; in the course of a few days granular crystals are formed, which must be edulcorated with cold water, dried by pressure in bibulous paper, dissolved in water, and precipitated by acetic acid.

Hæmatéin, when thus purified, forms a reddish-brown precipitate, and, on exsiccation, reverts to a dark-green metallic hue; with hot water it forms a brown solution, which, when rapidly evaporated, affords a succession of greenish crystalline pellicles, and on cooling deposits the hæmatéin either in a granular or gelatinous form. The ultimate components of these crystals are—

		Centesimally.	
	At. weight.	Theory.	Erdmann
40 Eqs. Carbon,...............	240	62·66	62·799
15 Eqs. Hydrogen,.............	15	3·91	4·135
16 Eqs. Oxygen,...............	128	33·43	33·066
1 Eq. Crystallized hæmatéin,..	383	100·00	100·000

With nitric, hydrochloric, and dilute sulphuric acids, hæmatéin forms red solutions. With ammonia a dark violet-colored granular powder is produced, which may be dried without loss of the base; its aqueous solution is deep purple, that in alcohol is brown, but becomes purple when water is added; by evaporating the aqueous solution in the air, it is decomposed. The elements of this compound of hæmatéin and ammonia, when dried over concentrated sulphuric acid *in vacuo*, were ascertained by **Erdmann** to be $C_{40}\ H_{22}\ O_{17}\ N_2$. The same chemist has also described compounds of hæmatéin with oxide of lead and oxide of copper.

Logwood, as already mentioned, is very hard and close in the fibre. When used chipped in small pieces it requires long boiling to extract the coloring principle. To obviate this, the wood is now generally ground fine, by which means the operation is much facilitated. To avoid loss by dust in grinding, owing to the dryness of the wood, it is moistened by water, which greatly enhances the appearance of the wood, by producing a richer color upon it, and does not affect its dyeing properties; but from the fact, that a slight alkalinity given to the water heightens still more the color of the wood, and greatly facilitates the extraction of the coloring matter, some parties are in the habit of adding a little lime to the water sprinkled upon it, and thus impart to inferior wood the appearance of the good quality. All such practices are hurtful to its dyeing properties, and exercise a baneful effect upon the colors produced, particularly on light tints. All alkaline matters applied to logwood tend to make the colors dyed by it more fugitive, especially if the wood has been long in contact with such substances. Their presence may be detected by putting a little of the ground wood in a test tube, keeping it at summer heat in distilled water for some time, and then testing the solution with delicate test papers.

Although there is no direct chemical means known which may be readily practised by the dyer for testing the quality of the logwood he is about to purchase, nevertheless his own experience and practice, if rightly applied, will form a very good security against any gross fraud.

Napier has shown the average ash from logwood to be 1·5 per cent.; any admixture of sand may therefore be detected, by burning a small quantity and weighing the ash. The quantity of moisture may be ascertained by weighing 100 grains, spreading this upon a piece of paper or any flat vessel, keeping it exposed for several hours to a heat of boiling water, and then weighing again. After these preliminary trials, by taking different samples so dried, and dyeing a given weight of mordanted cotton with a given weight of each, an accurate comparative estimate is obtained; and if a known good sample is tested along with those on trial, the purchaser will have no occasion to complain that he had no means of ascertaining the value of the article sold to him. Of course, as certain qualities of logwood are known to be better adapted for certain tints or colors than others, the comparative trials should be made with cotton impregnated with different mordants; and as samples of logwood are often found to differ only in having less or more water in them, the moisture lost by drying will always have to be considered in comparing different qualities. The natural moisture in logwood is found to be from 12 to 16 per cent., differing, no doubt, according to its age and the locality in which it has been kept.

MADDER.—*Garance*, French; *Faberröthe*, German —is the root of the *Rubia tinctorum*, a plant of which two species are distinguished by LINNÆUS. It is common in the South of Europe, and in many parts of the Levant, and is largely cultivated in Holland; it attains to about three feet in height, and has a long spreading fibrous root, which is the part used in dyeing. The best roots are of the size of a writing quill, or, at most, of the little finger. They are semi-transparent, reddish, have a strong odor, a smooth bark, and should be of two or three years' growth. The root is taken from the ground, picked, and exsiccated, in order to be ground and preserved. In warm climates, it is dried in the open air; elsewhere, stoves are made use of. The stringy filaments and epidermis, termed *mulle*, as also the pith, are removed, leaving nothing but the ligneous fibres. Dr. URE gives the following as the method employed in the department of the Rhone for the preparation of madder:—

The roots are dried in a stove heated by a furnace, from which the air is allowed to issue only at the moment when it is judged to be saturated with humidity. Above the furnace flue, which occupies a great portion of the floor, are three gratings, on which the roots are arranged in layers of about eight inches. At the end of twenty-four hours, those on the first grated floor directly above the stove are dry, and are taken away and replaced by those of the higher floors. The desiccated roots are then thrashed with a flail, passed through fanners similar to those employed for corn, and shaken upon a coarse sieve. The finer particles are again winnowed and passed through a still finer sieve. These operations are repeated five times, using sieves successively finer and finer, and putting aside each time the portion which remains on the sieve. The matter which finally passes through is rejected as sand and dust. After these manipulations, the whole of the fibrous substances remaining are cleaned with common fanners, and all foreign matters, which had not been before removed, are now separated. The roots are then divided into different qualities, for which a brass sieve is used, the meshes of which are from one-fourth to one-eighth of an inch in diameter. The finest portion is rejected, while the coarsest is considered of the best quality. These roots, thus separated, are carried into a stove of a construction somewhat different from the first. They are spread out in layers of about four inches in thickness, on large lattice-work frames, and the drying is known to be complete when, on taking up a handful and squeezing, the roots break easily. On quitting the stove, the madder is placed, still hot, into a machine, where it is cut small, and the portion of the bark reduced to powder is separated. This operation is repeated three or four times, after which resort is had to the bolter. The madder which passes through the brass meshes of the bolter is considered as common, and that issuing from the extremity of the bolter is called the flour. Lastly, the madder, after being subjected to these processes, is ground in a mill with vertical stones, and afterwards passed through sieves of different degrees of fineness. The madder of Alsace is reduced to a very fine powder, and it requires a much longer boiling to extract its tinctorial matter than is necessary for the *lizari* of the Levant. The prepared madders ought to be carefully preserved from humidity, as they readily imbibe moisture, in which case fermentation injures their color. D'AMBOURNEY and BECKMANN have asserted, that it is more advantageous to employ the fresh root of madder than that which has been desiccated, especially by means of stoves. But in its state of freshness, its volume becomes troublesome in the dye-bath, and uniform observation seems to prove that it ameliorates by age. Besides, it must be rendered capable of keeping and carrying easily.

In commerce, the name of *lizari* has for a long time been restricted to the entire roots of the madder, while that of *madder* is applied to the pulverized roots.

Lizari is very little employed for the purposes of dyeing, and there is hardly any but that of Avignon which is met with in the markets of France: the lizari of Cyprus is of rare occurrence, while the Alsatian product is never met with.

The powders called madders are distinguished according to their origin, into Dutch, Alsatian, and madder of Avignon, or of the Comtat.

Before GIRARDIN wrote upon this subject, no work of materia medica, or of applied botany, had given the history of these powders, nor the peculiar characters of each variety. His situation, however, enabled him to make a particular study of this important tinctorial product; and the following remarks are the results of many and various observations:—

Dutch madder has a strong and nauseous odor; its taste is sweet, but with a mixture of bitterness; its color varying according to the marks, and passing from a brownish to an orange-red. The brownish-red tint, however, is applicable only to the *mulle* madder of each kind. The term *mulle*, or *bilon*, is applied to the inferior quality of madder, which consists of a mixture of the smallest roots, of the fibres and epidermis of the larger roots, of earthy matters, and of the refuse from the sieves.

In general, its powder is stringy, that is to say, its state of division is sufficiently large to exhibit the structure of the root. It is coarser than the other kinds of madder, which might be attributed to negligence, since frequently portions of lizari are met with which have never been submitted to the operation of grinding. This rough state of comminution, however, is no defect, since it prevents fraud. This powder seems greasy to the touch. Exposed to the action of the atmosphere it readily absorbs moisture, and when, for the sake of ascertaining its quality, it is exposed to humid air, its orange-red becomes bright, rich, and deep. This madder, to use a commercial term, *works* more than others; that is, it presents more decided modifications of color by exposure to moisture.

Dutch madder is either stripped or the contrary. In the first case, the roots have been freed from their epidermis, which gives greater brightness to the powder; in the second, they have been triturated without undergoing this operation, when the powder is of a more sombre hue. This madder cannot be used while fresh; it must at least be a year in the cask: after three years it is in full vigor.

The *pale* powder, or that of the first year, having a yellow aspect, soon undergoes fermentation; the divided particles then unite with each other, agglomerate, and increase in volume to such a degree that, after from one to two years, the dilation is so great, that the bottoms of the casks present a very marked convex form. The madder is then so hard, that, in order to take it out of the cask, a mallet or chisel must be used.

It keeps several years after having attained its greatest tinctorial power; but after about three years, the layers which line the sides of the casks then begin to lose their brightness; the madder assumes a pale-brown color, and enters into decomposition, the process of which is slow but certain; it subsequently becomes quite extinct, and the madder has a brown-red hue. When partially decomposed, it may still be used for brown grounds or light colors; but when age has affected all the tinctorial principles, it can only serve as *mulle*.

The marks current in the French markets are—

Mulle, O,	or	Mulle.
Superfine,		Fine grappe.
Not stripped or stripped,		Superfine grappe.

The term *grappe*, signifying bunch, is employed when age has given consistence to the powder, and designates its state of agglomeration.

Alsatian madder, which has replaced the Dutch in France, although it does not possess all its qualities, has the following characters:—

The smell is more penetrating than that of the preceding; taste, less sweet, but equally bitter; color varies from brown to bright-yellow, according to the mark; and the state of division is coarser. It easily absorbs moisture from the atmosphere by exposure, and changes from yellow to a dark-red.

As is the case with the Dutch madder, it is not employed while fresh; it is in the best condition when about two years old. It deteriorates sooner than the former, and it grows very hard in the casks, cohering to the very centre, there being the same difficulty to extract it. The progress of decomposition is similar, and the product which has undergone this process can only be used for dark tints.

Alsatian madder is never known by the denominations *stripped* or *not stripped*, although the epidermis is removed; the following marks alone distinguishing the varieties:—

O,	Mulle.
M F,	Mi fine.
F F,	Fine fine.
S F,	Superfine.
S F F,	Superfine fine.

The third quality, F F, is most generally used; S F F is nearly an exception to the method employed by the Alsatians in grinding, who are strict enough in their marks to be unwilling to prepare it very fine.

It is principally at Strasbourg, Hagenau, and Geisselbrunn, that the so-called Alsatian madder is manufactured.

Madder of Avignon is most generally used at the present time, and even preferred to the other kinds, because the dyer and the calico-printer find it easier to modify the reds according to wish. It is especially since the peace of 1815, that the use of this madder has increased.

Of all the kinds of madder, this sort has undergone the most modifications; indeed, it is almost the only kind in which variations are made in the marks and quality. In Holland, and in Alsatia, the quality specified is generally conformable to the mark. In Avignon, on the contrary, each manufacturer has a mark to designate its quality; and the mark S F F, which with one is beautiful, is but middling with another. The result is, that the trader cannot trust to the mark alone, which presents a different tint in each manufactory. The madder of Avignon, therefore, can only be bought after having been subjected to some comparative test.

The characters of this powder are—odor, agreeable, slightly penetrating; taste, sweetish bitter; color, either rose, bright-red, or brown-red, according to the roots employed in the preparation, and to the degree of mixture; state of division very fine; powder dry to the touch.

When submitted to the action of the atmosphere, it absorbs moisture less readily than the other species, but it does not work less, and subsequently affords a pale, or very dark-red, according to whether the powder operated on was *rosy* or *palus*.

In Avignon, the name *Palus* is given to some tracts of land anciently covered with marshes; these grounds, enriched by animal and vegetal remains, are eminently suited for the cultivation of madder; the roots they produce being almost all red, and of a superior quality; whilst other kinds of soils yield rose-colored roots.

The powder from the palus madder is of a dull and rather unsightly red, but on drying it becomes blood-red, and the shade may be varied at pleasure. A small quantity goes much further than a large amount of the rose-colored root.

The powder from the latter is of a bright-red, bordering a little upon yellow.

The madder, which is half palus, half rosy, is brilliant, well received in the market, and affords very satisfactory results in dyeing. The lustre of the rosy madder mingling with the rich depth of the palus, produces a most beautiful red.

In Avignon the terms *stripped* or *not stripped* are unknown. There the word *épuration* is used. A madder is purified from three, five, seven, or ten, and even as high as fifteen per cent. This mode of expression, however, is pure quackery, for how is a root to be purified except by depriving it of its epidermis; and how can it be imagined that the root may contain so much more or less of it, as to require that the purification should sometimes be carried to fifteen per cent.? One would have to suppose, that the weight of the epidermis was to that of the root as 1 : 7, 10, or 15, which is not the case.

The Avignon product may be used immediately on leaving the mills; but that which has been preserved in casks for a year is decidedly preferable. It keeps well, and undergoes little or no fermentation; it does not cohere in a mass; after several years, however, it is decomposed with nearly the same symptoms as the other kinds: it is still used in this state. The small degree of eremacausis evinced, arises from its containing much less mucilaginous, saccharine, and bitter substances than the Dutch and Alsatian madder, for it is certain that the acid fermentation which is so energetically developed in the latter must be attributed to those substances.

Although pressed with great force into the casks, the madder retains much air between its particles, which, in time, acts upon the whole mass, giving it a uniform color, by oxidizing the primitive yellow principle, and changing it into a red. This theory, advanced by Decaisne, very well explains why the madder powders are improved in quality by being preserved.

The exsiccation of the roots in the stove has great influence on the tint of the madder of Avignon. If dried at too high a temperature, the powder is dull, but does not, however, lose in quality.

At first, only two kinds of Avignon madder were known, the yellow and the red. The first has since disappeared, and the rosy is now substituted for it. It is difficult to give positive information as to the marks, especially since the manufacturers have appeared to agree in their attempts to confuse them, and thus to deceive buyers.

The following were the only marks originally known:—

Mulle.	
F F,	Fine fine.
S F,	Superfine.
S F F,	Superfine fine.

These brands were applied to the casks without any other designations. The tint alone decided to what sort of root the powder belonged. At present they are, as before indicated, either palus, rosy, or a combination in equal proportions of both these kinds.

The following are the marks:—

Mulle, F F, S F F, S F F F, E X T F, E X T S F, E X T S F F. The quality known as mulle has no additional distinction; to the signs for the other kinds, there are added, however, P for palus, P P pure palus, R P P pure red palus, or R, signifying rosy. According to these designations, the absurd mark of E X T S F R P P, to be understood as *extra superfine pure red palus*, is by no means a rarity.

It must be confessed, says Girardin, that such absurdities can only exist in a country where fraud has made revolting progress. It often happens that the mark E X T S F, now used, is not equal to the old one of S F F.

The extra fine is especially manufactured from the heart of the ligneous portion of the root, and though less rich in tinctorial matter than the fleshy part or the bark, it affords a much more lively color.

The interior of the casks in which Avignon madder is packed, is generally lined with thick card-board, to prevent communication with the atmosphere, which blackens the powder, causes it to appear less beautiful, and, after a certain time, destroys much of its dyeing properties, which are also very quickly changed by light.

MM. Bucholz, John, and Kuhlmann gave the following as the constituents of the root:—

1. Red coloring matters.
2. Pale red, or fawn-colored matter.
3. Lignine.
4. Mucilaginous matters.
5. Gum and grape sugar.
6. Pectin and pectic acid.
7. Bitter and extractive principle.
8. An odorous resin.
9. Red resin.
10. Brown matter soluble in potassa.
11. Vegetal albuminous matters.
12. Various organic acids, partly combined with lime, viz., tartaric, malic, and pectic acids.
13. Mineral salts, carbonate, sulphate, and phosphate of potassa, chloride of potassium, carbonate and phosphate of lime, silica, phosphate of magnesia, and a remarkable quantity of tartrates of lime and potassa.

From these it will readily be perceived that the study of madder will involve a great many difficulties, and is an ample subject for investigation; and not a few of our eminent chemists, both in this and other countries, have engaged themselves in it.

The tinctorial principles of madder, notwithstanding numerous investigations, are as yet very imperfectly understood. Berzelius and Runge obtained and described five coloring matters—purple, red, orange, yellow, and brown.

Madder-purple may be procured in the following manner:—Boil the clean root repeatedly in a concentrated solution of alum, and filter whilst hot. On cooling, a brownish-red subsidence—consisting principally of *madder-red*—occurs, and must be removed by decantation. Next add sulphuric acid to the menstruum, which gradually throws down the purple. It may be purified by boiling in hydrochloric acid, digesting in alcohol; finally, distilling off most of the spirit, and allowing the residue to evaporate spontaneously.

Madder-red is abstracted from the aluminous deposit just mentioned, by boiling in dilute hydrochloric acid, and dissolving in alcohol. This is then boiled with a strong solution of alum, which causes the precipitation of the madder-red. It is purified by dissolving in ether, and the menstruum, on evaporating spontaneously, leaves it as a yellowish-brown crystalline powder.

Madder-orange requires a separate and distinct process. Clean madder roots are digested for about sixteen hours in eight parts of water, at a temperature of 60°. The infusion being filtered, gradually deposits minute crystals, which are collected, desiccated, and dissolved in boiling alcohol. The orange principle, which subsides on the cooling of the menstruum, is edulcorated in a filter with cold alcohol, till the filtrate is no longer tinged by sulphuric acid. This substance, when heated in a glass tube, exhibits similar reactions as madder-purple, except that the vapors are yellower; boiling solutions of alum form with madder-orange a yellow solution, depositing some of its color upon cooling.

Madder-yellow is very soluble in water, a property which characterises it from the other coloring principles; it has a gummy consistence, and forms no dye of any permanence; the better the quality of the madder, the less yellow it possesses. Dutch madder has generally a great quantity of madder-yellow.

Madder-brown.—This is a dark-brown substance, approaching to black, which is obtained during the preparation of the other coloring matters; it is neither soluble in alcohol nor water, and is of no known use as a dyeing agent.

The researches of MM. ROBIQUET and COLIN led them to the opinion, that only two important coloring principles exist in madder, which they termed *colorin* and *alizarin*, or *garancin;* the latter were first formed and described in 1828, but has since become a most important article in the dye-house, and will be considered more fully after giving some of the more recent chemical investigations into the nature of the compounds that exist in madder. Amongst the foremost in these investigations stands Dr. SCHUNCK. At the commencement of his researches, he says—RUNGE described five coloring matters which he obtained from madder, *madder-purple*, *madder-red*, *madder-orange*, *madder-yellow*, and *madder-brown*. This chemist states, as one result of his investigation, that he agrees with RUNGE in thinking that there is more than one coloring matter in madder, though he is of opinion that the substances which he enumerates and describes are not pure. Before, however, entering on this part of the subject, SCHUNCK first gives the results at which he arrived at in regard to alizarin. Alizarin is doubtless the most interesting and the most definite in its nature of all the substances contained in madder. It also presents itself the most easily to the observer, even on the most superficial examination. If madder be heated, spread out in a thin layer on a metal plate without carrying the heat far enough to char the woody parts of the root, its surface will be covered, in the course of a few hours, with small red or orange-colored crystals, which consist of alizarin. In the same way, any extract of madder, whether with water, alcohol, or alkalies, evaporated to dryness and gently heated, gives a crystalline sublimate of alizarin, which is variously colored from a light-yellow to a dark-red or brown. Now one of the first points to be ascertained in regard to this body was, whether it exists as such in the root, or whether it is formed by the process of sublimation. ROBIQUET, the discoverer, states that it pre-exists in the plant. He considered alizarin as the coloring principle of madder, and merely subjected it to sublimation for the purpose of purifying it. But his investigation presents us with no convincing proof of this opinion, for the extract of madder with water, alcohol, *et cetera*, from which he prepares his alizarin by sublimation, shows no trace of anything crystalline; and many chemists have asserted, in consequence, that it is a product of decomposition, being formed by the action of heat in the same way as pyrogallic, pyrotartaric acid, and many other bodies. SCHUNCK affirms, however, that it exists in the plant as such, having in more than one way obtained it in a crystallized state without the intervention of heat. If an extract of madder be made with cold water, a brown fluid is obtained, which produces no reaction on test paper. After being exposed, however, to the action of the atmosphere for some hours, it acquires a distinctly acid reaction; and if it be now examined carefully, there will be found floating about it a number of long hair-like shining crystals: these crystals are alizarin.

Dr. SCHUNCK afterwards found that this substance, here named alizarin, had in it two coloring principles; to the one he gave the name of *rubiacin*, the other being true alizarin.

He then says—it is necessary to state that the substance called alizarin, in the paper read on this subject, at the Southampton meeting of the British Association, is now termed rubiacin; and he is of opinion that the substance discovered by ROBIQUET, and called by him alizarin, does not agree in its properties with rubiacin; but after carefully comparing his account with the results obtained by himself, he has come to the conclusion that the substance to which he applied the name of alizarin is identical with that of ROBIQUET.

Alizarin has the following properties:—When heated on platinum foil, it melts and burns with a bright flame. When heated in a glass tube closed at one end, it melts and gives yellow fumes, which condense on the colder parts of the glass, forming an oil, which soon congeals to a mass of orange-colored crystals possessing a considerable lustre, which are unchanged alizarin. A carbonaceous residue is usually left in this case, but SCHUNCK has no doubt that, by carefully heating, it might be entirely volatilized. Alizarin is slightly soluble in boiling water. The solution has a yellow color, but so small is the quantity dissolved, that the alkali or earth usually contained in filtering paper is sufficient to render the solution pink, on being filtered to separate it from the excess of alizarin. Hence, no doubt, arises the statement found in books, that alizarin dissolves in water with a pink color. The boiling solution deposits it on cooling in yellow crystalline flocks. It is soluble in boiling alcohol. The solution has a deep yellow color, and deposits nothing on cooling; but, on evaporation, the alizarin is left in long needle-shaped or prismatic orange-colored crystals possessing a considerable lustre. The color of the crystals very much resembles that of bichromate of potassa. Concentrated sulphuric acid dissolves alizarin in the cold with a blood-red color. It is precipitated from this solution by water in flocks of a dull orange color. Dilute nitric acid decomposes it on boiling with an evolution of nitrous acid. If it is still mixed with fat, then the fat remains behind after the alizarin has been decomposed and dissolved by the nitric acid. It is not affected by hydrochloric or acetic acid. On passing chlorine into water in which alizarin is suspended, the color of the latter is changed to yellow, but it is seemingly not destroyed. It is decomposed by bichromate of potassa and sulphuric acid. A boiling solution of sesquichloride or nitrate of iron decomposes it with a copious evolution of gas, a pungent smell resembling that of aldehyd being at the same time given off. The product of this decomposition will presently be described. Chloride of gold is not reduced by it on boiling; but, on the addition of caustic potassa, metallic gold is deposited in shining scales. It is soluble in caustic and carbonated alkalies with a splendid purple color, and is reprecipitated by acids in flocks of a dull orange color. The solution in ammonia gives with the chlorides of barium and calcium precipitates of a splendid purple color; with sugar of lead, a light purple precipitate. The compound with alumina produced by introducing hydrate of alumina into an alcoholic solution of alizarin, is not decomposed by a concentrated solution of caustic potassa. The alcoholic solution gives with acetate of iron a dark purple precipitate; with acetate of copper, a light purple precipitate; with protochloride of tin no precipitate, except on the addition of ammonia, when a light red precipitate is produced. If alizarin and a piece of mordanted cloth be introduced into boiling water, and the boiling be continued for some time, the cloth becomes slowly dyed, and the mordants assume the tints peculiar to the so-called madder colors. The alizarin slowly disappears in the same measure as the cloth becomes dyed, even though less water had been taken than was sufficient to dissolve the whole quantity. It is evident, therefore, that, in the process of dyeing, the alizarin, which is dissolved in the first instance by the boiling water, is taken up by the mordants of the cloth; that then a fresh quantity is dissolved by the water, which is again absorbed, and so on, until all the alizarin has combined with the cloth, or until the mordants can take up no more. Hence the slowness with which madder-dyeing is effected. No doubt can, therefore, remain, that alizarin plays a great part in the production of madder colors. That it does not produce the whole effect in dyeing with madder, will be shown afterwards.

On subjecting alizarin to elementary analysis, SCHUNCK obtained the following results:—

I. 0·3205 gramme of crystallized alizarin dried in the air gave, on being burnt with chromate of lead, 0·6695 carbonic acid and 0·1210 water.

II. 0·3985 gramme of the same gave 0·8320 carbonic acid and 0·1850 water.

III. 0·3140 gramme gave 0·6565 carbonic acid and 0·1670 water.

These numbers correspond in 100 parts to—

	I.	II.	III.
Carbon,	56·97	56·94	57·02
Hydrogen,	4·19	5·13	5·87
Oxygen,	38·84	37·93	37·11
	100·00	100·00	100·00

The great discrepancy in the amount of hydrogen in the preceding analyses, arises from the circumstance that alizarin loses its water of crystallization with such extreme facility. No. I. was mixed with warm chromate of lead in a warm mortar; No. II. was mixed with warm chromate of lead in a cold mortar; and No. III. with cold chromate of lead in a cold mortar. In the case of No. I., therefore, it is seen that the heat of the chromate of lead and the mortar combined was sufficient to drive away more water than that which corresponds to 1·5 per cent. of hydrogen, though this heat was not greater than what might be borne by the hand. In order to determine the amount of water of crystallization, crystallized alizarin was heated in a water-bath until it lost no more in weight.

I. 0·4015 gramme treated in this way lost 0·0735 water.

II. 0·3575 gramme lost 0·0655 water.

Alizarin which had been deprived of its water of crystallization by heat, gave, on being burnt with chromate of lead, the following results:—

I. 0·2990 gramme gave 0·7575 carbonic acid and 0·1045 water.

II. 0·3005 gramme of a different preparation gave 0·7620 carbonic acid and 0·1095 water.

III. 0·2765 gramme of the same preparation as the preceding, gave 0·7010 carbonic acid and 0·1025 water.

In 100 parts it contains, therefore—

	I.	II.	III.
Carbon,	69·09	69·15	69·14
Hydrogen,	3·88	4·04	4·11
Oxygen,	27·03	26·81	26·75
	100·00	100·00	100·00

On analysing alizarin prepared by sublimation from pure crystals, SCHUNCK obtained the following numbers:

I. 0·3970 gramme gave 1·0115 carbonic acid and 0·1340 water.

II. 0·4110 gramme gave 1·0510 carbonic acid and 0·1375 water.

In 100 parts—

	I.	II.
Carbon,	69·48	69·73
Hydrogen,	3·75	3·71
Oxygen,	26·77	26·56
	100·00	100·00

It will be seen from this, that sublimed alizarin does not differ materially in composition from alizarin which has been freed from its water of crystallization.

Of the compounds of alizarin with bases, the lime, baryta, and lead compounds were prepared. The two former were prepared by dissolving alizarin in ammonia, and precipitating with chloride of calcium and chloride of barium, the latter by dissolving alizarin in alcohol, and precipitating with an alcoholic solution of acetate of lead. The latter forms a purple precipitate, which, after standing for some hours, becomes of a dull red.

The lead compound gave on analysis the following numbers:—

I. 0·4800 gramme gave 0·2095 oxide of lead and 0·0245 metallic lead, equivalent to 0·2359 oxide of lead.

0·5125 gramme burnt with chromate of lead, gave 0·7050 carbonic acid and 0·0780 water.

II. 0·5865 gramme of a different preparation, gave 0·3970 sulphate of lead, equivalent to 0·2920 oxide of lead.

0·6915 gramme gave 0·9370 carbonic acid and 0·1005 water. Hence was deduced the following composition:

	At. weight.	Theory.	Found. I.	Found. II.
14 Eqs. Carbon,	84	37·57	37·51	36·95
4 Eqs. Hydrogen,	4	1·78	1·67	1·61
3 Eqs. Oxygen,	24	10·75	11·70	11·65
1 Eq. Oxide of lead,	111·7	49·90	49·12	49·79
	223·7	100·00	100·00	100·00

The lime compound gave the following results:—

I. 0·4685 gramme gave 0·2065 sulphate of lime, equivalent to 0·0857 lime.

II. 0·4750 gramme gave 0·2125 sulphate of lime, equivalent to 0·0882 lime.

Assuming that the formula for this compound is $C_{14} H_4 O_3 + CaO + HO$, its composition would be as follows:—

	At. weight.	Theory.	Found.	
			I.	II.
1 Eq. Alizarin,	112	74·91		
1 Eq. Water,	9	6·03		
1 Eq. Lime,	28·5	19·06	18·30	18·58
	149·5	100·00		

The baryta compound gave the following:—

0·2450 gramme gave 0·1420 sulphate of baryta, equivalent to 0·0932 baryta.

Assuming that the formula of this compound is similar to that of the last, namely, $C_{14} H_4 O_3 + BaO + HO$, its composition would be as follows:—

	At weight.	Theory.	Found.
1 Eq. Alizarin,	112	56·65	
1 Eq. Water,	9	4·57	
1 Eq. Baryta,	76·68	38·78	38·03
	197·68	100·00	

Neither of these compounds loses the equivalent of water which it contains on being heated in a water-bath for several hours.

The composition of crystallized alizarin must, therefore, be as follows:—

		Theory.
14 Eqs. Carbon,	84	56·75
8 Eqs. Hydrogen,	8	5·40
7 Eqs. Oxygen,	56	37·85
	148	100·00

Or,

	At weight.	Theory.	Found.	
			I.	II.
1 Eq. Dry Alizarin,	121	81·76		
3 Eqs. Water,	27	18·24	18·33	18·32
	148	100·00		

It follows that alizarin dried at 212° must consist of—

	At. weight.	Theory.
14 Eqs. Carbon,	84	69·42
5 Eqs. Hydrogen,	5	4·13
4 Eqs. Oxygen	32	26·45
	121	100·00

If this be the true composition of alizarin, it follows that there exists a very singular relation between it and the composition of benzoic acid. The formula of benzoic acid is $C_{14} H_6 O_4$, and alizarin only differs from it therefore by containing one equivalent less of hydrogen. If alizarin be compared with isatin, it will be found that the latter only differs from the former by containing in addition the elements of one equivalent of cyanogen. The formula of isatin is $C_{16} H_5 NO_4 = C_{14} H_5 O_4 + C_2 N$.—*See Indigo.* Anthranilic acid differs in composition from alizarin in containing in addition the elements of amidogen, for the formula of anthranilic acid is $C_{14} H_7 NO_4 = C_{14} H_5 O_4 + NH_2$.

Alizaric Acid.—At one period of his investigation, SCHUNCK imagined that alizarin and rubiacin might be separated by boiling the mixture with perchloride of iron, in which case he expected the rubiacin to dissolve in the solution of the iron salt, and the alizarin to remain behind in combination with oxide of iron. He was not aware, at that time, that alizarin is decomposed by sesquichloride of iron. Before he had discovered this, however, he had taken about one hundredweight of madder, treated it with boiling water, added acid to the fluid, separated the brown precipitate by filtration, and treated the whole quantity of precipitate with sesquichloride of iron. The fluid was, after the addition of acid and filtration, evaporated to a sirup. After allowing the sirup to stand for some days, it was found filled with white crystals, bearing a resemblance to oxalic acid. Water was added to the sirup, which was filtered, and washed until the sesquichloride of iron was removed. The crystals bore washing with cold water without dissolving in any considerable degree. They were then dissolved in hot caustic alkali, filtered to separate some oxide of iron which remained behind, and sulphuric acid added to the fluid while still hot. On cooling, there separated a quantity of long shining white crystals, which were separated by filtration, and washed. SCHUNCK now found that they contained no oxalic acid, but that they bore a striking resemblance to benzoic acid. Indeed, some of the reactions are the same as those of benzoic acid, and it was only after having submitted it to an elementary analysis that he became convinced that it was not benzoic acid. The author termed this ***alizaric acid.*** It has the following properties:—

Its taste is acid. When heated on platinum foil, it melts and burns with a smoky flame, leaving no residue. When heated in a tube, it is completely volatilized, without leaving the least residue. The vapors condense in the colder parts of the tube, forming long white needles. This sublimate differs, however, in composition from the acid itself, and it may, therefore, be called *pyro-alizaric acid.* When heated in a tube with caustic lime, it is decomposed, and a yellow oil distils over, having a smell very nearly resembling that of benzin. It is soluble in boiling water; the solution has an acid taste, and reddens litmus paper. A concentrated boiling solution crystallizes on cooling. It is easily soluble in alcohol. Concentrated sulphuric acid dissolves it in the cold. On boiling the solution, no blackening takes place, and the alizaric acid distils over and crystallizes on cooler parts of the tube. It is easily soluble in alkalies. A concentrated alkaline solution gives crystals on the addition of a strong acid. The solution in ammonia gives no precipitates with the chlorides of barium and calcium. If, to the solution in water, chalk be added until all effervescence has ceased, the solution gives a crystallized lime salt on evaporation. This lime salt is decomposed on being strongly heated in a tube, becomes black, and gives an oil with an aromatic odor, which on cooling crystallizes. The aqueous solution gives with sesquichloride of iron a yellowish-white precipitate; with acetate of lead, a white precipitate; with nitrate of silver alone, no precipitate, but on the addition of ammonia, a white curdy precipitate, which, after some time, becomes crystalline. The reaction with sugar of lead distinguishes it from benzoic acid, which is not thereby precipitated. Its greater solubility in water, and its acid taste, are also distinguishing characteristics; but in most respects it will be seen that the resemblance between the two is very striking.

It is not necessary to prepare pure alizarin in order to obtain alizaric acid. SCHUNCK found the following to be the easiest method:—Nitric acid, of about specific gravity 1·20, having been put into a retort, garancin is introduced into the acid, and the liquid is heated until the red fumes have ceased to be evolved, and the color of the garancin has changed from dark-brown to yellow. The reddish-yellow acid liquid which is obtained, is filtered or strained to separate it from the woody fibre, *et cetera*, of the garancin, and evaporated to crystallization. A yellow crystalline mass is obtained, which is a mixture of oxalic acid and impure alizaric acid. After being washed with cold water to remove the excess of nitric acid, the mass is dissolved in boiling water, and chalk is added until all effervescence and acid reaction have ceased. The liquid is filtered, and the oxalate of lime remaining on the filter is washed with boiling water, until no more lime can be detected in the percolating liquid. The liquid is a solution of alizarate of lime. Hydrochloric acid is added to it, and it is evaporated to crystallization. A yellow mass is again obtained, which may be washed with cold water to remove the chloride of calcium, then redissolved in boiling water. It forms a yellow solution, which may be almost decolorized by animal charcoal. On again evaporating, the alizaric acid is obtained in large crystals. Should these crystals still retain a yellow tinge, which is generally the case, they must be redissolved in boiling water. By passing chlorine gas through the boiling solution, until every trace of color has disappeared, perfectly colorless crystals of the acid are obtained on cooling. Prepared in this way, it appears in large flat rhombic plates: it has the properties just described.

The salts of alizaric acid are mostly soluble. Alizarate of potash is formed by neutralizing a watery solution of alizaric acid with carbonate of potassa: it is obtained on evaporation as a deliquescent mass. Alizarate of lime is prepared by neutralizing alizaric acid with carbonate of lime, and evaporating to crystallization. It crystallizes in prisms possessing great lustre. Alizarate of baryta, prepared in the same way by means of carbonate of baryta, crystallizes in silky needles. Alizarate of silver, prepared by double decomposition, is soluble in boiling water, from which it crystallizes on the solution cooling. Alizarate of lead is an insoluble white powder, obtained by precipitation of the acid with acetate of lead. With ammonia, alizaric acid does not seem to form a neutral salt. On supersaturating a solution of the acid with ammonia and evaporating, the solution acquires during evaporation an acid reaction, and at length a salt crystallizes out in flat plates, which is probably a superalizarate of ammonia. All the salts of alizaric acid, when strongly heated, are decomposed with an evolution of a fragrant smell similar to that of benzin, and give, as a product of the decomposition, a thick brown oil, to which without doubt the smell is owing; while the carbonates of the bases, or the bases themselves, remain behind mixed with much charcoal.

The elementary analysis of alizaric acid gave the following results:—

I. 0·5250 gramme obtained by means of perchloride of iron and burnt with oxide of copper, gave 1·1015 carbonic acid and 0·1810 water.

II. 0·4670 gramme obtained by means of nitric acid and burnt with chromate of lead, gave 0·9865 carbonic acid and 0·1685 water.

III. 0·4475 gramme of the same preparation as the preceding, gave 0·9360 carbonic acid and 0·1625 water.

IV. 0·4395 gramme purified by means of chlorine and burnt with chromate of lead, gave 0·9335 carbonic acid and 0·1510 water.

These numbers give in 100 parts—

	I.	II.	III.	IV.
Carbon,......	57·20	57·61	57·10	57·92
Hydrogen,....	3·83	4·00	4·03	3·81
Oxygen,......	38·97	38·39	38·87	38·27
	100·00	100·00	100·00	100·00

Alizarate of lead was analysed with the following results:—

I. 0·8110 gramme gave 0·2665 oxide of lead and 0·2160 metallic lead, equivalent to 0·4991 oxide of lead.

0·6660 gramme gave 0·5810 carbonic acid and 0·00915 water.

II. 0·6230 gramme gave 0·2040 oxide of lead and 0·1655 metallic lead, equivalent to 0·3822 oxide of lead.

0·6515 gramme gave 0 5560 carbonic acid and 0·0860 water. Hence was deduced the following composition:—

	At. weight.	Theory.	Found.	
			I.	II
14 Eqs. Carbon,.......	84	23·37	23·79	23·27
4 Eqs. Hydrogen,....	4	1·11	1·52	1·46
6 Eqs. Oxygen,......	48	13·37	13·15	13·93
2 Eqs. Oxide of lead,..	223·4	62·15	61·54	61·34
	359·4	100·00	100·00	100·00

The baryta salt lost nothing in weight on being heated for several hours in a water-bath.

I. 0·6725 gramme of baryta salt dried at 212° gave 0·5245 sulphate of baryta, equivalent to 0·3442 baryta.

II. 0·7330 gramme gave 0·5700 sulphate of baryta, equivalent to 0·3740 baryta.

Its composition is therefore probably as follows:—

	At. weight.	Theory.	Found.	
			I.	II.
1 Eq. Anhydrous acid,..	136	46·26		
1 Eq. Water,..........	9	2·36		
2 Eqs. Baryta,..........	153·3	51·38	51·18	51·03
	298·3	100·00		

It is probable that the silver salt also contains two equivalents of base to one of acid.

It follows from the analysis of the lead salt, that the hydrated acid has the following composition:—

		Calculated.
14 Eqs. Carbon,.................	84	57·93
5 Eqs. Hydrogen,..............	5	3·44
7 Eqs. Oxygen,.................	56	38·63
	145	100·00

By the action of nitric acid on alizarin, the latter takes up three equivalents of oxygen without losing any hydrogen, for $C_{14} H_5 O_4 \times 3 O = C_{14} H_5 O_7$. It appears also that alizaric acid contains one equivalent of hydrogen less, and three equivalents of oxygen more, than benzoic acid.

Pyro-alizaric Acid.—When alizaric acid is heated it is totally volatilized, and forms a sublimate in the shape of long white needles, to which SCHUNCK has given the name of pyro-alizaric acid. By the action of heat alizaric acid loses water, or the elements of water. Pyro-alizaric acid is soluble in boiling water. The solution, however, produces exactly the same reactions as alizaric acid itself, and, on evaporation, large rhombic crystals are obtained, which have quite the appearance of the latter acid. It is probable, therefore, that, by solution in water, pyro-alizaric acid takes up again the elements of water, and is reconverted into alizaric acid. The following results were obtained on analysing this acid:—

I. 0·4405 gramme dried at 212° and burnt with chromate of lead, gave 1·0345 carbonic acid, and 0·1185 water.

II. 0·4255 gramme gave 0·9985 carbonic acid and 0·1215 water.

From these numbers it may be inferred that the composition is as follows:—

	At. weight.	Theory.	Found I	Found II.
28 Eqs. Carbon,.......	168 ..	63·87 ..	64·04 ..	63·99
7 Eqs. Hydrogen,....	7 ..	2·66 ..	2·98 ..	3·17
11 Eqs. Oxygen,......	88 ..	33·47 ..	32·98 ..	32·84
	263	100·00	100·00	100·00

Hence it follows, that by the action of heat two equivalents of alizaric acid lose three equivalents of water, and give one equivalent of pyro-alizaric acid, since $2\ (C_{14}\ H_5\ O_7) - 3\ HO = C_{28}\ H_7\ O_{11}$.

Rubiacin.—The other coloring matter found along with alizarin in the precipitate formed in aqueous extracts of madder by adding acids, and which Dr. SCHUNCK calls rubiacin, is prepared as follows:—The precipitate is boiled in alcohol till all soluble matter is taken up; the alcohol is then distilled, and the residue evaporated to dryness, when it has a dirty orange color; this is put upon a filter, and cold water poured upon it till it passes through colorless. That which is dissolved by the cold water is *rubiacin*. The mass left undissolved is then boiled in distilled water, and filtered hot; on cooling, it deposits alizarin. This process is repeated until the boiling fluid deposits nothing more on cooling. There are some fats also dissolved, and which disguise the alizarin. The insoluble matter left after treatment with boiling water, contains the rubiacin with fats. The alizarin is separated from the fats by boiling with an aluminous salt, which precipitates as a beautiful red color; the alumina is afterwards separated by a solution of caustic potassa.

The rubiacin is removed from the fats by a boiling solution of sesquinitrate or sesquichloride of iron, which produces a solution of a deep reddish color; this is filtered and treated with a little hydrochloric acid, producing a yellow precipitate, which is filtered and washed from the acid and iron salts. This precipitate is composed of rubiacin and rubiacic acid, the latter being formed by the action of the iron oxide on the former. It is now treated with boiling alcohol, which dissolves the rubiacin and the remaining fats, rubiacic acid being left. Rubiacin precipitates from the alcohol solution by cooling.

Rubiacin is most easily obtained in a state of purity from rubiacic acid. Rubiacin and rubiacic acid are mutually convertible, as they only differ from one another by a certain number of atoms of oxygen. Rubiacin is converted into rubiacic acid by the action of the sesquisalts of iron, and rubiacic acid may be reconverted into rubiacin by reducing agents, such as sulphide of hydrogen. In order, then, to obtain pure rubiacin, it is best to take a solution of pure rubiacate of potassa, to which a slight excess of caustic potassa has been added, and to pass sulphide of hydrogen gas through the solution for some time. Chloride of barium is then added, which produces a dark purple precipitate, consisting of rubiacin in combination with baryta. This is separated by filtration, and washed with cold water until the sulphide of barium and hyposulphate of baryta are removed, and then decomposed with hydrochloric acid, which leaves the rubiacin behind. After being washed with water, it is dissolved in boiling alcohol, from which it crystallizes on the solution cooling. It is obtained by these means in beautiful yellow crystalline plates and needles, having a strong lustre. The color is a little darker than that of neutral chromate of potash, and inclines more to green than to red. If there is a tinge of red in it, it is impure, and must be recrystallized. It has the following properties:—

It is a little soluble in boiling water, to which it communicates a reddish-yellow tinge. The solution deposits it on cooling in shining yellow scales. The alcoholic solution has a pure yellow color, without a tinge of red. It is precipitated from its alcoholic solution by water in yellow flocks. When heated on platinum foil it melts, and burns with a smoky flame, leaving no fixed residue. When heated in a tube closed at one end, it melts and gives yellow fumes, which condense in the colder parts of the tube in yellow crystals. If it be heated gradually at a moderate temperature, it may be almost entirely volatilized, leaving only a film of charcoal. Concentrated sulphuric acid dissolves it with a yellow color, and water precipitates it again in yellow flocks. The solution in sulphuric acid may be heated to the boiling point without becoming in the least degree black, and water still precipitates it. Concentrated nitric acid slowly decomposes it on boiling with an evolution of nitrous acid. Dilute nitric acid dissolves it with a yellow color on boiling, and on the solution cooling, it crystallizes out again in shining needles. It appears, therefore, that nitric acid does not convert it into rubiacic acid. Boiling acetic acid dissolves it, and deposits it again on cooling in yellow flocks. It is not affected by chlorine. It dissolves in a concentrated solution of sesquichloride or sesquinitrate of iron, forming a dark brownish-red solution, which on the addition of acid becomes yellow, and deposits yellow flocks. These flocks are no longer unchanged rubiacin, but rubiacic acid. It is a remarkable circumstance, that though rubiacic acid differs from rubiacin merely in containing a few atoms more oxygen, it is not formed from the latter by the action of nitric acid either dilute or concentrated, but is easily produced by the agency of the sesquisalts of iron, which seems to indicate that something besides the influence of oxygen is brought into play during the process. Rubiacin is soluble in carbonate of potassa with a blood-red color; the solution deposits after some time red flocks. It dissolves in caustic alkalies with a reddish-purple color, and is reprecipitated by acids in yellow flocks. The solution in ammonia gives with the chlorides of calcium and barium dirty red precipitates. The alcoholic solution gives with an alcoholic solution of acetate of lead, a dark-red precipitate. If into the boiling alcoholic solution hydrate of alumina be introduced, the alumina acquires an orange color, and the fluid is deprived of all its rubiacin. The compound with alumina thus formed dissolves entirely in caustic potassa, forming a purple solution, a characteristic which distinguishes it from alizarin, the alumina compound of which, as mentioned above, is insoluble in caustic potassa.

SCHUNCK arrived at the conclusion, that rubiacin cannot be considered as a true coloring matter, as it is impossible to dye with it. He has also shown that, contrary to the opinion which he was led to entertain in the first instance, rubiacin does not contribute to produce any effect in the process of madder-dyeing.

On subjecting rubiacate of potash and rubiacic acid to analysis, he obtained the following results:—

I. 0·4490 gramme rubiacate of potash gave 0·1090 sulphate of potassa, equivalent to 0·0589 potassa.

0·4350 gramme gave 0·7950 carbonic acid and 0·0900 water.

II. 0·3245 gramme gave 0·0790 sulphate of potassa, equivalent to 0·0427 potassa.

0·2890 gramme gave 0·5315 carbonic acid and 0·0665 water.

From these numbers it may be inferred that the salt is composed as follows:—

	At. weight.	Theory.	Found.	
			I.	II.
31 Eqs. Carbon	186	51·63	51·50	51.82
7 Eqs. Hydrogen,	7	1·94	2·29	2·55
15 Eqs. Oxygen,	120	33·31	33·09	13·16
1 Eq. Potassa,	47·27	13·12	13·12	13·16
	360·27	100·00	100·00	100·00

I. 0·3785 gramme rubiacic acid, dried at 212°, and burnt with oxide of copper, gave 0·7940 carbonic acid and 0·0845 water.

II. 0·3605 gramme of another preparation gave 0·7610 carbonic acid and 0·0795 water.

III. 0·4670 gramme of the same preparation as the preceding, gave 0·9775 carbonic acid and 0·1050 water.

Hence was deduced the following composition:—

	At weight.	Theory.	Found.		
			I.	II.	III.
31 Eqs. Carbon,	186	57·76	57·21	57·57	57·08
8 Eqs. Hydrogen,	8	2·48	2·48	2·45	2·49
16 Eqs. Oxygen,	128	39·76	40·31	39·98	40·43
	322	100·00	100·00	100·00	100·00

0·3150 gramme rubiacin, dried at 212°, and burnt with oxide of copper, gave 0·7740 carbonic acid and 0·0935 water.

This gives the following composition:—

	At. weight.	Theory.	Found.
31 Eqs. Carbon,	186	67·63	67·01
9 Eqs. Hydrogen,	9	3·27	3·28
10 Eqs. Oxygen,	80	29·10	29·71
	275	100·00	100·00

The formula of rubiacin being $C_{31}\ H_9\ O_{10}$, and that of rubiacic acid $C_{31}\ H_8\ O_{16}$, it follows that, when rubiacin is converted into rubiacic acid, it loses one equivalent of hydrogen and takes up six equivalents of oxygen, and that, when rubiacic acid is reconverted into rubiacin, it loses six equivalents of oxygen and takes up again one of hydrogen. This oxidation and reduction is accomplished with the same certainty and precision as any similar process with inorganic bodies.

Rubiacic Acid.—The method of obtaining this acid through the instrumentality of the sesquisalts of iron has been previously described. There is no reason for supposing that it exists as such in the plant. It is doubtless a product of the oxidation of rubiacin. To obtain it in a state of purity, pure crystallized rubiacate of potash is dissolved in water, and hydrochloric or any strong acid is added, which precipitates the rubiacic acid in the shape of a yellow powder. It has a pure lemon-yellow color. It cannot be obtained in a crystalline form. It is slightly soluble in boiling water, to which it imparts a yellow color. It is also slightly soluble in boiling alcohol, with a yellow color. The solution deposits nothing on cooling, but water produces in it an iridescent appearance, caused by the deposition of minute crystals. When heated on platinum foil, it melts and burns with a bright flame, leaving no residue. When heated in a tube it melts, and gives fumes which condense on the colder parts of the tube to an oil, which solidifies but does not crystallize. Concentrated sulphuric acid dissolves it with a yellow color, and water precipitates it again in yellow flocks. On heating the solution in sulphuric acid it becomes darker, but no gas is given off; some decomposition seems, however, to have taken place in consequence of the heating, for water now produces no precipitate. Concentrated nitric acid dissolves it on boiling, and slowly decomposes it with an evolution of nitrous acid. It dissolves in a solution of sesquichloride of iron with a dark reddish-brown color, and is reprecipitated by acids in yellow flocks. It is not affected by bichromate of potassa and sulphuric acids even on boiling.

The potassa salt is the only salt of this acid which SCHUNCK has hitherto examined. It crystallizes from a hot concentrated solution in water in needles and prisms of a light brick-red color. On being heated it is instantly decomposed, giving rise to a slight detonation. The aqueous solution has a blood-red color, but is quite transparent. The addition to it of caustic potassa causes it to assume a beautiful dark purple color, and a concentrated boiling solution does not crystallize on cooling after the addition of caustic potassa. The watery solution gives with solutions of the earthy and metallic salts the following reactions:—With chloride of calcium, it gives an orange-colored crystalline precpitate; with chloride of barium, a yellow precipitate; with sulphate of magnesia, a yellow precipitate; with alum, an orange-colored precipitate;

with protosulphate of iron, a greenish-grey precipitate; with sesquichloride of iron, a slight reddish-brown precipitate, which is soluble in the boiling fluid; with acetate of lead, a red precipitate; with sulphate of copper, a dull red precipitate; with nitrate of silver, a yellow precipitate, which is not changed by boiling; with subnitrate of mercury, a yellow precipitate; with protochloride of mercury, a crystalline yellow precipitate; with protochloride of tin, a dirty yellow precipitate; with bichloride of tin, a light yellow precipitate; with chloride of gold, a yellow precipitate, not changed by boiling the fluid.

SCHUNCK's analyses of rubiacin, rubiacic acid, and rubiacate of potassa, afford results which agree very well with one another. These analyses give for rubiacin the formula $C_{31}\ H_9\ O_{10}$; for rubiacic acid, $C_{31}\ H_9\ O_{17}$; and for rubiacate of potassa, $KO, C_{31}\ H_7\ O_{15}$. It therefore appears that rubiacic acid contains seven atoms of oxygen more than rubiacin, and the facility with which they may be converted one into the other is easily conceivable. In rubiacate of potash, two atoms of water existing in rubiacic acid are replaced by one atom of potash, which is not usually the case with potash salts. SCHUNCK does not, however, consider these formulæ as completely established, since he was obliged, from want of material, to operate on such extremely small quantities.

Rubian.—This substance is obtained, as mentioned above, by treating the brown precipitate produced by an acid in an extract of madder with cold water, after having removed the excess of acid. It has the following properties:—

In thin layers it is perfectly transparent, and of a yellow color. When dry it is brittle. It is soluble in water; the solution has an extremely bitter taste. A concentrated boiling solution forms a jelly on cooling. It is precipitated from its aqueous solution by all acids, in yellow flocks. It is decomposed by nitric acid. In the watery solution, lime and baryta water produce red flocculent precipitates; sesquichloride of iron, a dark reddish-brown color, but no precipitate; acetate of lead, a brown flocculent precipitate; nitrate of silver, a flocculent precipitate; chloride of mercury, no precipitate; tincture of galls and solution of glue, no precipitates. The solution imparts a slight tinge to mordanted cloth, but so slight that this substance cannot be considered as a coloring matter. The solution deposits nothing during evaporation at all resembling apothem, and it therefore is not extractive matter. It dissolves in alcohol with a yellow color, and in alkalies with a red color. It dissolves in concentrated sulphuric acid with a red color; the solution, on being heated, becomes black, and gives off sulphurous acid. When heated on platinum foil, it melts, swells up immensely, and burns, leaving some ash. When heated in a tube, it melts and gives yellow fumes, which condense and form a crystalline sublimate, very much resembling rubiacin, so that SCHUNCK was induced to think that there is some relation subsisting between these two substances.

Pectic Acid.—There can hardly be a doubt that that part of the brown precipitate which is insoluble in alcohol, but soluble in water, is pectic acid, as will be seen from its behavior towards reagents, which is as follows:—It is soluble in water; the solution has a light yellow color, and reddens litmus paper slightly. In the watery solution, acids produce white flocculent precipitates; alcohol, a gelatinous white precipitate; lime and baryta water, thick gelatinous pink precipitates; common salt, a flocculent precipitate; nitrate of potassa, a flocculent precipitate; acetate of lead, a gelatinous reddish precipitate; sulphate of copper, a gelatinous greenish precipitate; chloride of mercury, no precipitate. On evaporating the watery solution, the substance separates on the surface of the fluid in the shape of a pellicle, and is left at last as a brownish extract, which may easily be detached from the sides of the vessel. In solutions of caustic and carbonated alkalies, it first swells up, and, on heating the fluid, it dissolves with a light-red color, forming slimy fluids, from which it is precipitated by acids in flocks. Solutions of salts, even of alkaline salts, produce precipitates in the alkaline solutions. It is decomposed by boiling concentrated nitric acid. When heated on platinum foil, it burns without melting, leaving a considerable ash. It seems that the pectic acid from madder retains in combination with it a portion of coloring matter, from which it cannot be separated. Hence the red color with which it dissolves in alkalies.

Rubian can be converted into different bodies by the action of acids upon it. Some of these are alizarin and rubiacin; and it is possible that some process may yet be found by which the whole of this apparently useless compound may be converted into useful products.

Besides the facts named, there are two kinds of resin, termed Alpha and Beta resin. The yellow coloring matter xanthin, soluble in cold water, has also been examined, and is stated to have the following properties and effects in the operations of dyeing:—

Xanthin has a disagreeable taste, between bitter and sweet. The watery solution is yellow. It is soluble in alcohol, and is left after evaporation in the same state as before. It is insoluble in ether. On adding hydrochloric or sulphuric acid to the watery solution, and boiling for some time, a peculiar smell is evolved, the solution becomes gradually dark-green, and a dark-green powder is deposited. This is the most characteristic property of xanthin. Nitric acid does not produce the same dark-green powder, or any deposit on boiling; nevertheless, the powder which has once been formed by means of hydrochloric or sulphuric acid, is not dissolved by boiling nitric acid, but only turned yellow. Acetic acid produces no effect. Oxalic acid gives a white precipitate of oxalate of lime. Bichromate of potassa and sulphuric acid produce no effect on a solution of xanthin, even on boiling. On adding caustic potassa to the solution it turns brown, and on boiling a slight smell of ammonia is evolved. Lime and baryta water, acetate and basic acetate of lead, the acetates of alumina, iron, and copper, nitrate of silver, chloride of mercury, and a solution of glue, produce no precipitate or effect whatever in a solution of xanthin. In fact, it does not seem to be precipitated by any reagent whatever without undergoing decomposition.

Mordanted cloth acquires no color in a boiling solution of xanthin, if the latter is in its yellow deoxidized state; but if the solution has become brown by contact with the air, then both the alumina and the iron mordant acquire in the boiling solution a brown color, while the unmordanted parts, which should remain white, become of a brown tint. Hence it follows that xanthin is injurious in madder-dyeing, and must contribute, together with the two resins, in impairing the purity of the colors, and sullying the whiteness of those parts which should attract no color. To get rid of the xanthin is one object of changing madder into garancin.

Dr. **SCHUNCK** concludes his papers with the opinion, that alizarin is the substance that produces the dye with madder. He says—

In order to prove analytically that alizarin is the substance which produces madder colors, several yards of cloth which had been dyed purple with madder, but not soaped, were treated with hydrochloric acid, which removed the oxide of iron, and left an orange-colored substance on the cloth. After washing the cloth in cold water until all the acid had been removed, it was treated with caustic alkali. The brownish-red solution thus obtained was supersaturated with an acid, and the reddish-brown precipitate formed was thrown on a filter, and well washed with cold water: it was then treated with boiling alcohol. The alcoholic liquid, which was dark-yellow, was spontaneously evaporated, and gave crystals of alizarin mixed with a powder resembling beta-resin, and a few yellow micaceous plates, which were probably rubiacin. There remained a brown residue insoluble in alcohol, part of which dissolved in boiling water, and proved to be pectic acid. On treating some cloth which had been dyed with madder and then soaped, with hydrochloric acid as before, and then with caustic alkali, was obtained a purple solution, in which acids produced a yellow precipitate. This precipitate was treated with boiling alcohol like the other; it gave a yellow liquid, which on evaporation afforded crystals of alizarin, together with white masses of fat acid. Hardly any residue remained undissolved by the alcohol.

Simultaneously with the investigation of Dr. **SCHUNCK**, Mr. **HIGGINS** undertook a series of experiments upon the same subject, with the results at once interesting to the chemist and useful to the dyer, as the following extracts will show:—

The various analyses of madder lead to the same conclusion as Dr. **SCHUNCK**, in his recent valuable paper *On the Substances contained in Madder*, namely, that there are three coloring matters capable of isolation—xanthin, a yellow; an orange, which he names rubiacin; and alizarin, a red. To this latter alone he ascribes all the tinctorial power of madder, an opinion from which Mr. **HIGGINS** differs; and the object of his present paper is to show that, under proper circumstances, the other two coloring matters have a great influence on its dyeing properties.

The difference in results seem to have arisen from the use, in one case, of boiling water to extract the principles, and in the other of cold or tepid water; the temperature having a remarkable influence on the products of extraction.

The Editor will here state the method employed by Mr. **HIGGINS** to separate from each other the three coloring matters; observing that, when separated, they differ little in their properties from those described by Dr. **SCHUNCK**.

The madder was on a conical calico filter, and washed well with boiling water till the liquor came away only faintly colored, and had no particular taste. Mr. **HIGGINS** objects altogether to boiling madder in water, as he finds that substances are obtained by so doing which have no existence in normal madder, being the result of decomposition: and the action ought to be as brief as possible. The extract by hot water, when cold, is acidulated with sulphuric acid, which causes a flocculent precipitate, which is collected on a filter. The precipitate contains rubiacin and alizarin, with some pectin. The deep yellow filtrate contains all the xanthin, slight traces of alizarin and rubiacin, some sugar, and the various organic and inorganic salts.

The filtrate is neutralized with carbonate of soda, and a very small quantity of hydrate of alumina added; the mixture is digested at a temperature of 130° Fahr. for about half an hour, and then filtered; by this means the traces of rubiacin and alizarin are removed, and the xanthin left, if not too much alumina has been used. To the filtrate is added baryta water, to throw down sulphuric and phosphoric acids; and after the separation of the baryta salts, sufficient subacetate of lead to throw down all the xanthin: some chloride and an organic salt are precipitated at the same time. The red lake is washed with a little cold water to remove some chloride of lead, sugar, *et cetera;* it is then diffused in water, and sulphide of hydrogen passed through; the xanthin remains attached to the sulphide of lead. This is thrown on a filter, and washed with cold water to remove the organic acid; it is then repeatedly boiled in water, and filtered. Xanthin dissolves with a rich yellow color. The solution is evaporated to a sirup in a water-bath, and, if necessary, neutralized with baryta, the evaporation completed, and the dry mass treated with absolute alcohol. Pure xanthin dissolves, and may be again evaporated to dryness.

The precipitate by sulphuric acid from the watery extract of madder is washed, first with water acidulated with sulphuric acid, and afterwards with a little pure water. About an equal bulk of fine chalk is then mixed up with it, and the mixture repeatedly boiled in water and filtered till the solution, at first dark-colored, becomes a faint pink only; the mixed solutions are acidulated with sulphuric acid, and the greenish-yellow precipitate collected, washed to remove acid, and dissolved in alcohol; the solution evaporated down to one-fourth of its volume, and an equal measure of water added. The precipitated rubiacin may be again dissolved in hot alcohol, and crystallized therefrom.

The alizarin is contained in the insoluble chalky matter left after the separation of rubiacin. This is digested with dilute hydrochloric acid at a gentle heat, cooled, filtered, and again treated with dilute acid, then washed on a filter till free from acid, alizarin remains, and may be crystallized from alcohol. It is obtained in much greater quantity from the madder which had been treated with boiling water at first. This washed madder contains principally alizarin, with a small quantity of rubiacin. It is boiled three or four times with a weak solution of alum to separate the rubiacin; it is next boiled with a saturated solution of alum for a quarter of an hour and filtered, and this process repeated till the madder is perfectly exhausted, and has become an ash-grey; the mixed liquors are cooled to 90° Fahr., and made sharply acid with sulphuric acid; after several hours the alizarin will have separated; the separation may be assisted by violent stirring occasionally. The filtered precipitate may be purified in the same manner as rubiacin.

Having described the isolated coloring matters, Mr. HIGGINS endeavors to show that the action of cold or tepid water on madder is attended with peculiar effects, and that by proper treatment all the xanthin and the greatest part of the rubiacin may be made to disappear, the change being accompanied by an increase in the tinctorial power; and since, of the three coloring matters, alizarin only can be made to dye colors, proving that alizarin and rubiacin result from changes in the xanthin.

When madder is mixed with cold water, stirred three or four minutes, and then filtered through fine calico, a deep reddish-brown liquid is obtained, tasting sweet at first, and then disagreeably bitter. A drop let fall upon white calico stains it a deep yellow, in the same way as a solution of pure xanthin does. When the liquid is allowed to stand an hour or two, it becomes gelatinous if the solution has been strong, and an orange-red flocculate precipitate falls. When this is filtered out, the liquor appears to have undergone a change, and is much diminished in intensity of color. It is now sweet only to the taste, without a trace of the bitterness so remarkable before; and a drop applied to calico stains it only a pale reddish color, with no shade of yellow. The powder filtered out has a very intense tinctorial power. The filtrate, on acidulation with sulphuric acid, gives more precipitate of the same nature, and remains a pale yellow, similar to the saturated solution of rubiacin and alizarin in a dilute acid. From some of the freshly-filtered solution of madder, xanthin was separated in the following manner:—Subacetate of lead was added to throw down all coloring matter; the lake washed and decomposed by sulphide of hydrogen, the metallic sulphide boiled in water several times, the mixed liquors neutralized with ammonia, and a small quantity of hydrate of alumina added; the mixture digested half an hour, and filtered from the lake of alizarin and rubiacin. On evaporation to dryness and treatment with alcohol, abundance of xanthin was obtained of the usual properties. The filtrate from the madder liquor which had stood till changed, was examined in like manner for xanthin, but without any being found. The red powder which had separated was dissolved in alcohol, precipitated by subacetate of lead, and the lake decomposed by sulphide of hydrogen. On boiling the sulphide in water, an orange liquor was obtained, from which, on cooling, flocks of rubiacin and alizarin fell; the pale orange liquor then evidently contained no xanthin. The sulphide boiled in alcohol yielded abundance of alizarin and rubiacin.

It was evident from this experiment, that in the madder liquor left to spontaneous action, all the xanthin had become changed into some coloring matter. To see what was the nature of this change, Mr. HIGGINS took some madder liquor quite freshly made in the cold, and added some solution of acetate of lime, which precipitates alizarin. The dark-red precipitate of alizarin lime having been separated, a dark reddish-brown solution remained: part of this was acidulated with hydrochloric acid, when a few yellow flocks fell, which when washed were found to be pure rubiacin. When mordanted cloth was attempted to be dyed with this powder, only the faint shades of rubiacin were obtained. The deep yellow filtrate from the rubiacin, when left to stand several hours, deposited no more flocks, and ultimately became green, as does solution of pure xanthin under the same circumstances.

Another portion of the filtrate from precipitation by acetate of lime was diluted a little with water, and allowed to stand about four hours; it had then lost the intense bitterness of taste, and retained only that of acetate of lime. On acidulation by hydrochloric acid, copious yellow flocks fell, which when filtered out left the filtrate a pale yellow; they were proved to be rubiacin, and had no tinctorial power. The yellow filtrate was examined for xanthin, but only a very small quantity was found.

Another portion of the original filtrate was set aside for about eight hours, when a quantity of reddish-orange powder had subsided, and the supernatant liquor was much diminished in intensity of color. The filtered precipitate, after treatment with dilute acid and washing, had a very strong tinctorial power; it was dissolved in alcohol, diluted a little with water, and lime-water added; a dark-red precipitate appeared, suspended in a red liquid. The filtered precipitate, washed with boiling water and decomposed by hydrochloric acid, was found to be pure alizarin; the filtrate from it, acidulated with hydrochloric acid, gave yellow flocks of rubiacin. The quantity of alizarin in the powder was greater than that of rubiacin; the liquor from which it had subsided was acidulated with hydrochloric acid, when a further quantity of powder was obtained, consisting of both rubiacin and alizarin, but more of the former. The filtrate from it was a pale yellow, and contained no traces of xanthin.

In these experiments, the madder liquor, from which all alizarin had been taken, and which had then no power to dye, by spontaneous action acquired a further portion of alizarin, and consequently recovered its power of dyeing. As the xanthin had totally disappeared during the process, the formation of alizarin must have been at its expense. The action is not however direct, as by stopping the process before any precipitation has occurred, only rubiacin is obtained, whilst, as before, xanthin has disappeared. It is evident, then, that the xanthin has become first rubiacin and afterwards alizarin.

This reaction does not result from oxidation, since it was found to take place equally well *in vacuo*; and as numerous experiments on the pure substance with various oxidizing agents failed totally to produce any alizarin, Mr. HIGGINS was induced to consider it the result of fermentation produced by a peculiar nitrogenized matter found in madder, and to be similar to the reaction between starch and diastase, where the starch becomes first dextrin and afterwards sugar.

This action becomes very probable from various experiments, in which it is found that the madder changes are best produced under circumstances favorable to the ordinary action of ferments, and are stopped by such substances as destroy their action.

In the foregoing experiments the changes undergone in cold water have been described, but, as in all other fermentations, a proper increase of temperature is attended with more rapid results. The best temperature is from 120° to 130° Fahrenheit. Water added to madder, and the mixture kept at that temperature, rapidly changes in appearance and taste; it gradually becomes redder, loses its bitter taste, and becomes more sweet; the yellow disappears, and the liquid, tested from time to time by dropping on white calico, is found constantly diminishing in intensity of color. In about half an hour all xanthin has disappeared; and the madder, if examined, is found to contain abundance of rubiacin and alizarin: if it was rich in xanthin, there will be at this stage a preponderance of rubiacin, so much so as to give an orange solution with boiling alum liquor, without much shade of pink. If the fermenting action be continued, the rubiacin is found gradually diminishing, and the alizarin proportionably increasing; the action is complete in about two hours and a half; and if the madder be now tried, only a small quantity of rubiacin is found; and the color of the alum solution is pink, but not quite so pure as that produced by pure alizarin, as the last portions of rubiacin are not easily removed by this process; a small fraction of the quantity originally found still remains.

Good madder contains sufficient ferment to convert an excess of xanthin into available coloring matter. Mr. HIGGINS made several experiments with different quantities, and found twenty per cent. additional to be the greatest quantity madder would convert.

With a view to place the utility of xanthin in dyeing beyond all doubt, the last-mentioned chemist made the following experiments:—

1. Two equal portions of the same madder were taken, and an equal quantity of water at 120° Fahr. added to each; to one, one-tenth of its weight of dry xanthin was added. They were kept at the same heat for half an hour, then in each was put an equal quantity of mordanted cloth of the same pattern, and they were heated gradually on a sand-bath, observing that the heating of the two dyeings progressed equally. At the end of an hour and a half, when the heat was 180° Fahr., the dyed cloth was removed, washed, and dried: the piece dyed with the ten per cent. additional xanthin was much darker and better dyed than that with madder alone; the whites were equally good.

2. The same experiment was repeated with twenty per cent. additional xanthin with increased advantage.

Two equal portions of madder were again taken: to one a certain quantity of water at 120° Fahr. was added, and the heat continued for half an hour; a certain quantity of dilute sulphuric acid then added, the mixture filtered, and the mass washed with a known quantity of dilute sulphuric acid, and afterwards with a known quantity of water.

The other portion was mixed with the same quantity of water and dilute acid as the former, filtered, and washed with the same quantity of dilute acid and water. The two portions thus treated were used to dye equal quantities of mordanted cloth, with the usual precautions. The one which was subjected to spontaneous action, previous to washing with acid, dyed full and rich shades; that from which the xanthin had been washed out unchanged, dyed shades very many times weaker.

In this experiment, the two madders were under exactly equal circumstances, except that one of them was allowed to ferment the xanthin; yet the difference in result was very great, and could only arise from the xanthin becoming available coloring matter. Mr. HIGGINS considers these experiments as clearly demonstrating the value of xanthin in madder-dyeing.

With this theory of madder, the operation of dyeing becomes much more intelligible. It is known that, to dye well with madder, the process must be begun at a low temperature, and the heat gradually raised. The application of the theory will be this:—The xanthin, on immersing the madder in water, immediately begins to decompose, becoming rubiacin; this in its turn becomes alizarin, and then the combination between it and the mordanted cloth takes place. The dyeing is begun by the alizarin already existing in the madder, and continued by the quantity continually formed. The slow heating of the liquor is very favorable to the change taking place. Generally, the temperature is about 130° at the end of the first hour; long before that, however, the xanthin has become rubiacin, and part of this alizarin, the remainder of the time being occupied in completing the change; the alizarin, being removed from solution as fast as formed, has probably some influence in accelerating the change of rubiacin. This will be the final action; and when the mordants are saturated, there will always be a small residue of rubiacin, which has a tendency to dull the shades; and hence the superior brightness of those dyed with garancin, which contains no rubiacin. Examination of the residual dye liquor generally shows a small quantity of rubiacin, which gives it an opaline appearance; there is also always alizarin united to woody fibre and lime. Examination of the dyed cloth, of whatever color, gives only alizarin, as was proved by SCHUNCK.

The fermentation and improvement of madder, when kept in the cask, is readily explained by supposing the xanthin gradually to change into alizarin: this is particularly noticed in Dutch madders, which abound in xanthin. Many substances and salts, added to a madder-dyeing, weaken its influence very much. An examination of the residual liquor uniformly shows the xanthin remaining unchanged, and the dyed effect has only been produced by the quantity of alizarin originally in the madder.

Having thus detailed experiments on normal madder, Mr. HIGGINS describes the results which he made on that preparation of it called garancin.

He found it to contain only one coloring matter, alizarin, and to be remarkably free from rubiacin, xanthin, pectin, and the nitrogenous matter. In no way was he able to separate any of these substances from the specimens he operated upon. The peculiar utility of garancin consists in all substances being removed which have an injurious influence on the action of alizarin.

As to the greater proportional dyeing power of garancin over madder, Mr. **HIGGINS** coincides in the opinion of Dr. **SCHUNCK**, that the lime salts being removed, no alizarin can remain combined with lime, and that in garancin dyeing all coloring matter is used up, whilst in madder only two-thirds are used.

Colorin.—It has been already stated that **ROBIQUET** and **COLIN** had obtained two tinctorial matters from madder, which they termed colorin and garancin. The former is considered to be impure alizarin; it is the substance left by distilling the alcoholic tincture made by treating garancin with spirit of wine. By dilution with water it is precipitated from the spirit, and when dried forms a dark-yellow mass; it is not much used in the arts.

Garancin.—**ROBIQUET** and **COLIN**, so early as 1828, not only prepared and described garancin, but, in conjunction with a French merchant, took out a patent for its manufacture and sale, under the name of *charbon sulphurique.*

The following is the process as described in their specification:—The madder is immersed in from five to six parts of cold water, and allowed to macerate all night, in order that the portion of the coloring matter which dissolves at first may have time to subside; the whole is then thrown on linen strainers, and when the liquor has percolated, the grounds are pressed: this operation is twice more repeated. After these three washings, which serve to remove a green substance, besides sugar, mucilage, and other soluble substances, the marc still moist and well crushed is mixed with sulphuric acid, equal to half the amount of madder first employed: it is, however, requisite that this acid should be diluted more or less with water, according to the temperature; this is done just before using it, in order to turn to account the heat set free by the mixture. The acid thus diluted is poured quite hot over the madder; it is then agitated as rapidly as possible, and when the mixture is well affected, the temperature is raised to 212°, and maintained for about half an hour. At the end of this time the substance is again mixed with a suitable quantity of water, filtered, and edulcorated on the strainers, until the liquid passes off perfectly insipid. It is then pressed, dried, and passed through a sieve.

In this operation, say the patentees, the acid has undergone no alteration; it has merely become weaker, and charged with some calcareous salts, which do not prevent its being employed in the manufacture of sulphate of soda. The first washing-water might also be turned to account, since it contains much sugar, which might easily be converted into alcohol.

Garancin was first introduced into commerce by the house of **LAGIER** and **THOMAS** of Avignon, towards the year 1829, who had bought the process and the patent from **ROBIQUET** and **COLIN**; but this product did not meet with success in the market. The neutral state in which it was delivered, not affording any correction to the calcareous waters ordinarily used in the Rouen print-works, and the action of their alkali on the coloring principle not being properly understood, the experiments which were made with it on a large scale were far from corresponding to those made with smaller quantities, and threw it into great discredit. It was not until about the year 1832, that the same house in Avignon, assisted by the advice of chemists, again commenced some trials, the results of which proving satisfactory, led to the belief that its use might become of importance. At this epoch, however, the madder-prints in vogue being very dark, and requiring a strong dye, could not be produced with garancin; the great quantity of tinctorial matter which they required, prevented its use on account of its price; but in 1835, the issue of certain kinds of prints requiring very bright colors, again drew the attention of manufacturers to garancin, and it was generally adopted and approved of.

Many persons, foreseeing how important its consumption might become, started establishments for the manufacture of it on the expiration of the patent of **ROBIQUET** and **COLIN**. Want of experience in this process caused these first manufacturers to obtain but imperfect products, and many soon left off; but shortly after, other speculatists, profiting by the experience of their predecessors, again took it up, and in 1843, according to **GIRARDIN**, there were from twelve to fifteen manufacturers of garancin at Avignon, and one or two in Alsatia.

The manufacturers of Avignon employ only the madders of the Comtat; those of Alsatia are, it is said, obliged to add a small quantity of the former to the madder which they grow, in order to increase the quantity of coloring matter of their product.

From 1839, this substance began to be generally employed in several of the principal print-works of Rouen, among others by **SCHLUMBERGER-ROUFF**, who manufactured the garancin which he used according to the following method:—

After having ground the already pulverized madder on a table by means of a thick wooden roller, it was placed in a leaden basin, then moistened with a little water, and half its weight of sulphuric acid, having a specific gravity 1·834, poured over it, whilst two men continually stirred the mass with shovels, walking around the basin. When the carbonization was ended, it was washed five or six times in barrels, the product drained upon linen, dried in a chamber by means of steam heat, and subsequently ground. This garancin was very acid, and could not be used for violet colors.

Since that period the manufacture of garancin has greatly extended; and although different modifications have been introduced as the result of observation in manufacture, very little change has been adopted upon the main principles of the manufacture upon that described above.

Up to the present time, it has not been possible to class garancin according to its quality. Each manufacturer seeks to obtain the best products with regard to the quantity of tinctorial principle, and also with regard to the brightness of the tints; but the impurity of the first matters, and the neglect of circumstances often in themselves very trifling, but, in reality, of great consequence, often cause the products of the same manufactory to vary considerably. In trade, garancin is met with which affords four times more coloring substance than the madder which was employed to obtain it, whilst other samples give but two and a half.

This want of regularity is as much dependent on the quality of the madder employed, as on the operations necessary in the production of the garancin; there is so much danger of charring the madder too much or too little by the acid, that it is quite impossible to produce two identical samples during a year. In large establishments, it is hardly possible to make fifteen or twenty barrels which will be nearly alike; for which purpose it is even necessary that the whole bulk of roots required should be treated at the same time. In general, a good garancin possesses three times as much tinctorial matter as madder of superior quality.

The same mode of classification has not been adopted for the garancin as for the madder; the former is only distinguished by the name of the manufacturer.

In 1843 a patent was taken for extracting garancin from the waste madders of the dye-house, which has been productive of great saving and advantage. The substance of the process thus patented is:—

The invention consists in manufacturing a certain coloring matter called garancin from refuse madder, or madder which has been previously used in dyeing, such madder having ordinarily been thrown away as spent and of no value, and the said coloring matter called garancin having been produced heretofore from fresh or unused madder. A large filter is constructed outside the building in which the dye-vessels are situated, formed by sinking a hole in the ground, and lining it at the bottom and sides with bricks without any mortar to unite them. A quantity of stones or gravel is placed upon the bricks, and over the stones or gravel common wrappering, such as is used for sacks. In a tub adjoining the filter is kept a quantity of dilute sulphuric acid, of about the specific gravity of 105, water being 100. Hydrochloric acid will answer the several purposes, but sulphuric acid is preferred as more economical. A channel is made from the dye-vessels to the filter. The madder which has been employed in dyeing is run from the dye-vessels to the filter; and while it is so running, such a portion of the dilute sulphuric acid is run in and mixed with it as changes the color of the solution and the undissolved madder to an orange tint or hue. This acid precipitates the coloring matter which is held in solution, and prevents the undissolved madder from fermenting or otherwise decomposing. When the water has drained from the madder through the filter, the residuum is taken from off the filter and put into bags. The bags are then placed in a hydraulic press, to have as much water as possible expressed from their contents. In order to break the lumps which have been formed by compression, the madder or residuum is passed through a sieve. To five hundredweight of madder in this state, placed in a wood or lead cistern, one hundredweight of sulphuric acid of commerce is sprinkled on the madder through a lead vessel similar in form to the ordinary watering-can used by gardeners. An instrument like a garden spade or rake is next used, to work the madder about so as to mix it intimately with the acid. In this stage the madder is placed upon a perforated lead plate, which is fixed about five or six inches above the bottom of the vessel. Between this plate and the bottom of the vessel is introduced a current of steam by a pipe, so that it passes through the perforated plate and the madder which is upon it. During this process, which occupies from one to two hours, a substance is produced of a dark-brown color approaching to black. This substance is garancin and insoluble carbonized matter. When cool, it is placed upon a filter and washed with clear cold water until the water passes from it without an acid taste. It is then put into bags, and pressed with a hydraulic press. The substance is dried in a stove and ground to a fine powder under ordinary madder stones, and afterwards passed through a sieve. In order to neutralize any acid that may remain, from four to five pounds of dry carbonate of soda for every hundredweight of this substance are added and intimately mixed. The garancin in this state is ready for use.—Sealed August 8, 1843.

Girardin gives the following as the behavior of garancin towards reagents:—

Cold distilled water communicates, after twenty-four hours of contact, a pale yellowish color; with boiling distilled water, it gives a pale reddish-yellow tint; cold calcareous water tinges it after twenty-four hours, but less than cold distilled water; boiling calcareous water occasions a somewhat paler hue than distilled boiling water; the tint with cold lime-water is paler after twenty-four hours than that with distilled boiling water, or that with boiling calcareous water; water acidulated with sulphuric acid, gives, after some hours, a slightly greenish-yellow; water acidulated with hydrochloric acid, reacts in a similar manner, but the tint is darker; cold distilled water acidulated with nitric acid, causes a rather dark tint, and the blackish-grey powder becomes of a brownish-red, resembling madder browned by age; with cold distilled water acidulated with acetic acid, the tinge becomes faint-yellow; acetic acid of 1·0704 specific gravity, gives, after several hours, a beautiful reddish-yellow color; caustic ammonia immediately occasions a reddening, and after twenty-hours the liquor is strongly colored crimson-red, so intense, that it is no longer transparent in a great mass; on the addition of water slightly alkalized by ammonia, it immediately assumes a beautiful claret color; caustic soda communicates a dark reddish-brown hue; with water charged with carbonate of soda, it quickly acquires a bright reddish color of Burgundy wine; cold alum-water causes it to become almost immediately a chrome red; boiling alum-water gives with it immediately a dark-red hue, and on cooling, flakes of the same color, but paler, are deposited; with alcohol of specific gravity 0·863, it assumes rather quickly a slight reddish-yellow tint; hydrated ether gives the same reaction.

As illustrative of the applications which some of these investigations upon madder have given rise to, the two following patents are quoted:—

Julian took a patent, in 1851, for extracting the coloring properties of madder, and for obtaining a spirit from the water that has been used in the extracting operation. The latter has been noticed under the article **Alcohol**. See page 116.

Whatever the quality of the madder, it may be treated according to this invention, which is carried into effect as follows:—Two hundredweight of madder, reduced to powder, are thoroughly mixed or diluted with from one hundred and thirteen to one hundred and eighteen gallons of water—according to the fineness of the powder—and the liquid is then run through a filter of woollen cloth, fixed upon a frame within a tun or vessel which receives the water, and is furnished with a tap for discharging the same. The filter is constructed to contain six hundredweight of madder, so that, when the above operation has been thrice performed, it will be full. The water is then drawn off into large wooden tuns, and the residue, which is now a wet paste, is put into linen bags or baskets, and subjected to the action of a hydraulic press, in order to extract the remaining water which is added to that before drawn off. After the paste has been well pressed, it is placed in receptacles heated to from 120° to 160°; and when it is perfectly dry, it is reduced to powder, and passed through a sieve. The patentee states, that a given quantity of this product—which he calls *flowers of madder*—when employed in dyeing, will have a greater effect than a like quantity by weight of the madder from which it has been extracted.

The water collected from the filter and hydraulic press is put into large wooden tuns, placed in a room heated to from 70° to 85°, where it is retained until alcoholic fermentation takes place, or for the space of five or six days. If by that time the alcoholic fermentation is not produced, the patentee puts into the tun five gallons of boiling water, in which ten or twelve pounds of yeast have been dissolved. On finding that the density of the water is reduced to a certain point, it is known that the alcoholic fermentation has been produced; and the liquid is then submitted to the process of distillation, in order to obtain a spirit therefrom.

A patent was granted in 1852, to C. A. KURTZ, for the preparation of madders and munjeet, by combining therewith preparations having a tendency to produce fermentation. For this purpose a liquor is first made in the following manner:—Twenty pounds of crushed malt are boiled in one hundred gallons of water from twenty to thirty minutes; after which, about forty pounds of bran are stirred in, and the menstruum allowed to stand until the malt and bran fall to the bottom, after which the clean liquor is run off, and the remainder filtered. From sixty to sixty-five gallons of the infusion are added to one hundred gallons of water, which is of such a temperature that the mixture will be about 112°. This is put into a vessel capable of containing about two hundred and sixty to three hundred gallons, and about three hundredweight of madder or munjeet are added, and the whole stirred at intervals of from ten to fifteen minutes, until it becomes homogeneous. This is to be left to rest till signs of fermentation appear; these are to be checked by repeated agitation during a period of from sixteen to eighteen hours; the mass is then to be filtered, pressed, dried, ground, and packed in the usual way.

The patentee remarks, that in place of malt and bran, other grain or matters may be employed in preparing a mash or liquor, which will tend to produce fermentation in like manner, though he believes that malt and bran are the best for the purpose. He further observes, that although he has been particular in stating the materials and exact quantities and temperatures, according to the best of his knowledge, he does not confine himself thereto, as they may be varied without departing from his invention, so long as extraneous matter be employed to induce fermentation.

Adulteration of Madder.—On account of the high price of madder, and especially from the facility of introducing into it, when sold in the form of powder, foreign pulverulent matters, which the most practised eye cannot detect, this root is subject to a number of sophistications which cannot be too fully exposed.

There are two kinds of adulteration. Sometimes earthy or mineral matters are incorporated with ground madder; at others, vegetal substances having a semblance of color are added to it.

According to GIRARDIN, the inorganic substances which have been introduced, or which are still found in powdered madder, are brick-dust and yellow ochre, yellowish sand, clay, or argillaceous earth. A madder which contains earthy substances grates between the teeth when chewed.

A small quantity introduced into a large test glass, and diluted with about one hundred times its weight of water, quickly deposits the greater portion of the earthy substances at the bottom of the vessel. When the suspended madder is decanted, and the deposit agitated with a fresh quantity of water, the earthy substances are isolated, and may be examined.

However, to determine the proportion, more exact processes must be had recourse to. The best is that of incinerating a portion in a platinum crucible.

Five grammes of the madder under examination are first dried completely at 212°, weighed with great exactness, and then put into the platinum crucible, previously tared; the lid is then superposed, and heat gradually applied. When perfectly incinerated, the crucible and its contents are allowed to cool, and then weighed. The weight of the crucible and ash being deducted from the gross weight of the crucible employed, gives the proportion of inorganic residue. This contains the fixed mineral matters of the root, and also the earthy substances foreign to the chemical constitution of the root, and which have been accidentally or fraudulently mixed with the madder.

Some experiments which GIRARDIN and LABILLARDIÈRE made on a large scale in 1828, showed that madder which is very pure, and quite free from epidermis, or any foreign earthy matter, and dried with care, gives, by incineration, five per cent. of ash; that the lizari of Provence, stripped of its pellicle, gives, on an average, 8·80 per cent. ash.

According to SCHLUMBERGER, one hundred parts of Alsatian lizari, washed in distilled water, and dried at 212°, gave 7·20 per cent. of ash; whilst one hundred parts of lizari of Avignon, prepared in the same way, afforded 8·766.

According to CHEVREUL, lizari from the Levant, dried at 212°, gives 9·80 per cent. of ash.

When an Avignon madder, SFF, the mark most generally used, subjected to the test of incineration, gives a greater weight of ash than five per cent., which **Girardin** took as the means of numerous experiments, the excess must be attributed to the presence of foreign earthy or sandy matters, either arising from adulteration or a careless preparation of the powder.

When the excess over this is only from three to four per cent., it is probably due to some fault in the preparation of the madder, the manufacturer not having sufficiently separated the epidermis—which is always coated with the earth which surrounds the root—by grinding; but when the ash amounts to nine or ten per cent. of the madder employed, it is the result of fraud.

The madders of Avignon obtained from the merchants give very variable results with respect to the proportion of ash which they furnish, as the following table shows:—

		Per cent. of ash, Girardin.
In six experiments	the mulle madder gave	4·00
" seven "	" SF "	" 12·40 to 20·00
" eighteen "	" SFF "	" 7·40 " 23·00
" four "	" SFFRP	" 12·00 " 16·00
" three "	" SFFP "	" 10·00 " 10·80
" seven "	" EXTF "	" 10·00

The vegetal substances which are introduced into the madders are powders of little or no value, such as sawdust, almond shells, bran, the bark of the pine-tree, mahogany, red saunders, fir, and logwood.

The sophistication by these different matters is much more prejudicial to the dyer than that by mineral ingredients; for besides diminishing, like the latter, the quantity of coloring principle in a given weight of madder, they also injure the dye, either by absorbing the coloring matter, or by preventing the hues becoming so brilliant.

Unfortunately, the means of detecting this kind of fraud are neither so rigorous nor so simple as the process for determining the presence of mineral adulterants. It is extremely difficult to find with what kind of vegetal substance a madder has been deteriorated; it is mostly only possible to discover that there is a mixture, and the best way is to ascertain the tinctorial power of the sample under examination. Many methods have been proposed for this purpose, but the greater part of them have some defect, generally being too difficult, and too long of execution. That of **Robiquet** and **Colin** may be performed in the following manner:—Dry the samples at 212°, and treat them with two hundred or two hundred and fifty grammes of water, the temperature of which should not exceed 68°, otherwise a portion of the red coloring matter would be dissolved. The whole, after having been left in contact for about three hours, is thrown upon a filter, the insoluble portion is washed with two hundred or two hundred and fifty grammes of cold water, after which it is dried in the water-bath and weighed.

One part of the insoluble matter is then put into a small glass balloon, with forty parts of water and eight of alum; the whole is heated, and after boiling for a quarter of an hour, the liquor is filtered whilst in a state of ebullition.

The residuum on the filter is again washed as before, and the filtrate from the various samples is precipitated by sulphuric acid. The weight of the subsidence so produced in each liquor represents the proportion of coloring matter.

This mode is based upon the insolubility of alizarin in cold water, whilst the boiling solution of alum dissolves it all.

Chevreul, however, says that a portion remains undissolved.

Meillet's process is the following:—Take about four and a half gallons of water, heated to 140°, and dissolve in it about four and a half pounds of alum; add thereto about twenty-two pounds of madder, bring the whole gradually to the boiling point, and keep it at that temperature for half an hour. The whole is then thrown upon a cloth filter, and pressure applied to the solid matter; after having repeated this treatment three times, the madder is exhausted. After the various filtrates are mixed together, and left at rest for a while, the clear portion is decanted, and before it has completely cooled, the operator pours into it six hundred and twenty-five grammes of sulphuric acid, having a specific gravity of 1·848, diluted with twice the bulk of water, taking care to stir the liquor incessantly whilst adding the acid. Thick reddish flakes are precipitated, which soon subside, and the menstruum from red-purple becomes greenish-yellow. The supernatant liquor is then decanted, the residuum is washed several times, and a mass is left which, after drying in the air, is in the state of shining scales of a reddish-brown color; it is alizarin, but not quite pure. The precipitate, whilst still moist, should be heated with once and a half its weight of carbonate of potassa, dissolved in twelve or fifteen times its bulk of water; the alkaline carbonate is converted into sulphate, which produces a fine red precipitate, and this, according to **Meillet**, is pure alizarin, of which Avignon madder, when submitted to this treatment, yields two or two and a half per cent.; but it is necessary, in such trials, to compare the result obtained with that given by samples of the same kind and name which are known to be genuine. The coloring power of madder may also be determined by the colorimeter of **Labillardière**, which has been described in the treatise on **Indigo**, see page 588. The type madder, and that under examination, are dried at 212°, and a note is kept of the respective quantities of hygrometric water they contain.

Twenty-five grammes of each sample are then mixed with two hundred and fifty grammes of water at 68°. After three hours of contact, the whole is thrown upon a linen cloth. A second maceration is made with the same amount of water, and for the same period. The madders are then washed with two hundred and fifty grammes of cold water, dried at 212°, and weighed, in order to ascertain the proportions of soluble, saccharine, and mucilaginous matters which they have lost by these preliminary washings, which, however, only remove an insignificant amount of tinctorial principle.

Five grammes of each of the two madders are then introduced into glass globes with forty parts of water, and six parts of pure alum, boiled for a quarter of an hour, and the liquids filtered. The grounds are washed with two parts of hot water. Two other decoctions, similar to the first, are made, and each time the residue is washed in a similar manner. The products of the three decoctions are combined, and the liquids from the two samples compared by the colorimeter, by means of which it is easy to appreciate the different intensity of color; for if one hundred parts of the mixed decoction of each sample be introduced into the tubes, and water added to that which has the deeper tinge, until it is brought exactly to the degree of intensity of the other, the graduations will at once indicate in what ratio they differ.

But as madder is often adulterated with pulverised dyewoods, such as logwood, Brazil-wood, *et cætera*, other trials should be simultaneously resorted to. **Girardin** dyes with a given weight of pulverised madder, known to be of superior quality, a certain quantity of cotton prepared with different mordants. The pieces of calico employed for the experiment should all be of equal weight, and about two and a half or three inches square, and should be dyed with increasing proportions of madder, from ten to one hundred and fifty grains; a scale of intensity of color is thus prepared with each mordant, the degrees of each scale corresponding to a known weight of the madder taken as type.

The dyeing must be performed with care as follows:—Take a suitable number of wide-mouthed flasks, and put them into a pan placed over a naked fire, and containing water at 100° or 104°. Pour into each of the flasks one and a half pint of distilled water, also a piece of the mordanted piece of madder required. Place a thermometer into the pan, which should now be carefully heated, avoiding variations of temperature, and in such a way that an hour and a half may elapse before the bath attains 167°. After this period, the temperature must be raised to the boiling point for half an hour. The samples of calico are then withdrawn, rinsed with cold water, and dried.

After this treatment they are divided into two equal portions; one-half is preserved in that state, the other is immersed for half an hour at 106°, in a solution consisting of twenty-five grains of curd soap, and one and a half pint of water: the tissue is next taken out, rinsed with cold water, and returned to a similar bath, but to which eight grains of tin have been added. This bath is kept boiling for half an hour. The piece of calico should be carefully rinsed, dried, and kept sheltered from the light.

After having prepared a scale as above directed, it is sufficient afterwards, in order to determine the value of a sample of madder, to dye pieces of calico of the same description, with known weights of the madder under examination, and this value, compared with that taken as type, is then easily determined.

Instead of remnants of calico, skeins may be employed, weighing one hundred and fifty grains, for which, from three to four hundred and fifty, or five hundred grains of pulverised madder are used to form a scale of the colors.

Considering the minutiæ and the number of operations which it is necessary to have recourse to, in order to form a just estimate of the relative worth of madders, it is evident that an examination of them by a simple inspection, as is customary with the merchants, can afford no precise information, and must indeed lead in many, if not in most cases, to erroneous conclusions. The commercial process consists in placing samples of madders—each about thirty or forty grammes—side by side on a sheet of paper, in small heaps, which are flattened, and their surfaces rendered smooth with the back of an ivory spatula. They are then removed to a cellar, or some moist situation, where they remain from twelve to fifteen hours. At the expiration of this time, the quality is judged of according to the brightness and tint of the powder.

But, as **Schlumberger** has observed, this method does not even approximately show the richness of the madders, since a somewhat long contact with the air is sufficient to render them darker, and many circumstances may change their tint, without thereby causing a variation in their tinctorial value. On the other hand, the old madders, of a dull tint, may be far superior to others of a more beautiful color. The merchant's and broker's method of trial often places the manufacturer in a false position, by obliging him to brighten the hue of his powders, in order to make them more saleable, and that sometimes to the injury of the tinctorial power, thus facilitating the adulteration of the madders by mixture with foreign substances, suitably colored and pulverised, which serve to heighten the tint of the powder, and it is impossible to ascertain the presence of these mixtures by exposure in the cellar. **Girardin** purposely made mixtures of madder, of powders of mahogany, and of sandal-wood in known proportions, and these compounds, when tried by the merchants, who thought themselves very skilful in their estimation by the above process, were considered by them to be pure madders of first quality.

Indeed, as before observed, the truest way of arriving at the value of madder, is by a direct estimation of the amount of coloring matter. The most exact process hitherto known is that published by **Schlumberger** in 1836, and as modified by **Scheurer**. But this method, which is founded on the solubility in weak acetic acid of the tinctorial principle of madder, is unfortunately too sensitive, and requires such an amount of manipulative skill as to prevent its becoming generally employed.

The mode of procedure adopted by **Girardin** is as follows:—

Fifty grammes of madder are treated with fifty grammes of concentrated sulphuric acid. The whole is left in contact for some hours, too elevated a temperature being carefully avoided; the charcoal obtained is mixed with water, and thrown upon a filter; it is then washed until the water passes through quite insipid, and next dried at a temperature of 212° in the water-bath. It is afterwards reduced to a fine powder, and macerated for two hours, at three distinct intervals, with cold alcohol, containing a little ether, in order to free it from fatty matter which it retains. The powder is thrice boiled in alcohol, having a specific gravity of 0·834, employing each time about two hundred and fifty grammes. When this is no longer colored by ebullition, the alcoholic liquors are mixed, distilled in a small glass retort to the consistence of a sirup, and the concentration of the liquid completed in the water-bath, in a weighed porcelain crucible. When the extract is perfectly dry, its weight is ascertained. This represents the proportion of tinctorial principle contained in the weight of madder originally taken; the per centage is easily known.

This process is rather long, and does not give, especially on a small scale, the absolute proportion of coloring substance contained in the madder; there is also a slight loss, but by acting comparatively, a sufficient approximation is obtained.

These processes, which require great care and nicety of manipulation, are not suitable to the ordinary workmen, and can only be attempted in such works as employ practical chemists. What is required is an easy method, so simple in manipulation that a dyer with ordinary intelligence and hands can perform it. The only process yet recommended, and suitable for ordinary use, is that of dyeing samples of the same weight of cloth or yarn previously mordanted; and, for this purpose, every dyer should keep beside him samples of madder of known good quality for comparison; and by so doing, and by using mordants of a different sort—such as the aluminous and iron—not only the depth of tint may be well ascertained, but also the presence of other dyewoods by the well-known peculiarity of tint which they give with these mordants.

Munjeet.—This is the root of the *Rubia munjista*—cordifolia—called sometimes *Indian madder*, on account of its being used by the Indians, and even preferred by them to madder for some of their dyeing operations. It is found in commerce in bundles, consisting of stalks of two or three feet in length, and varying from the thickness of a quill to that of the little finger. The red coloring matter it contains is somewhat similar to that of madder, being alizarin. It may be separated in the same way by the action of sulphur, forming garancin, for which purpose it is extensively employed; but the quantity obtained from it is not so great as from inferior madder. It dyes a very bright color, of a scarlet tint. The dyeing quality of the roots is much improved by first heating them to ebullition with a little water having sumach in it, and afterwards adding the required quantity of water for dyeing and entering the goods. It is not much used, however, in the state of a root either for cotton or woollens, but is mostly converted into garancin, the quality of which is somewhat similar to that obtained from spent madder, the tint of color it produces being a little brighter.

Pittacal.—This is a beautiful coloring matter obtained from tar. When the latter substance is freed from acid, and baryta water added to it, there is produced a precipitate of a deep blue color. When collected and dried, it forms a deep blue solid mass, strongly resembling indigo, assuming also a coppery lustre when rubbed. It has often been mistaken for indigo by the dyer; from which, however, it may be very easily detected by a few simple tests. It has neither smell nor taste; it is insoluble in water, but may be suspended in that liquid in such a state of division as to pass through a paper filter. It dissolves in acids, giving colored solutions. With acetic acid it gives a deep rose color, from which it is again precipitated of a fine blue. It is in this way very sensitive to acids and alkalies, and has been recommended as equal, if not superior, to litmus as a test agent. It is not subject to alteration by air and light, a property valuable in dyeing. It gives a violet-blue with acetate of lead, chloride of tin, acetate of alumina, and ammoniacal sulphate of copper; thus its application to dyeing is easy, still its introduction as a tinctorial agent has not yet been attended with that success which its discoverer had anticipated.

Quercitron is the inner bark of the *Quercus nigra* or *tinctoria*. The tree is a native of North America, but has been introduced into France and Bavaria. Its dyeing powers were first published by Bancroft in 1784; and a law was passed by Parliament, in 1786, securing to him the exclusive use and application of it as a dye-stuff, for a certain term of years.

A decoction of quercitron bark has a yellow-orange color: if it be made very strong, it deposits a portion of the tinctorial matter on cooling. It contains a great quantity of tannic acid, which is always dissolved in the menstruum, and which gives the solution of bark a greater variety of uses. A decoction of the bark gives the following reactions:—Alkalies deepen the color of the solution; lime occasions a yellowish-red precipitate; protochloride of tin causes a yellowish-red subsidence; alum produces a slight deposit in the cold, but more when hot. Acetates of alumina and lead afford reddish-yellow precipitates, while that given by the same salt of copper is greenish-yellow. Salts of iron throw down a dark olive-green precipitate, passing into brown. Sulphuric, hydrochloric, and nitric acids, cause the formation of reddish-yellow flocculi.

Chevreul gave the name of *quercitrin* to the yellow coloring matter of quercitron bark. He obtained it in small laminæ or scales, of a pale greyish-yellow, by slowly concentrating an infusion or decoction of the bark, and allowing it to cool. According to this chemist, this substance is accompanied in the bark by red tinctorial bodies, and by brown principles. These owe their origin, in part at least, to the alteration of the quercitrin. The stale infusion of quercitron gives but a small quantity of dye; a great portion of the quercitrin is deposited, and that remaining in solution is of a dark hue, and its dyeing quality is much impaired.

In 1840, Bolley instituted some experiments on the yellow coloring matter. He obtained it by exhausting the pulverised bark with strong alcohol in a displacement apparatus, precipitating the tannin by gelatin or by a little lime, and evaporating the filtered liquid. This procedure causes the deposition of yellow crystalline crusts, which may be purified by washing with water, then dissolving them in alcohol, adding some water, and evaporating the solution, which affords a crystalline powder of a sulphur color, approaching to a chrome-yellow. Bolley applied the name of quercitric acid to this substance, because it reddens litmus perceptibly, and combines with bases. He represents it by the formula $HO, C_{16} H_8 O_9$, and its lead salt by $Pb O, C_{16} H_8 O_9$.

Preisser obtained quercitrin in the following manner:—A small quantity of gelatin was first added to the aqueous decoction of quercitron, so as to precipitate all the tannin. The filtrate was then treated with a little hydrate of lead, which produced a dirty-brown precipitate. The decanted liquor was of a very beautiful golden-yellow color, and yielded an abundant brilliant yellow deposit on the addition of hydrate of lead. This last lake, when well washed and decomposed by a current of sulphide of hydrogen, afforded a colorless liquid, which, on evaporation *in vacuo*, gave white needles of pure quercitrin.

According to the last-mentioned authority, quercitrin is colorless, and has at first a slightly sweet, subsequently a bitter taste. It is very soluble in water, in alcohol, and in ether. In contact with the atmosphere, it gradually becomes bright yellow, and by degrees the solution deposits yellowish-white flakes, having a crystalline appearance. The aqueous solution, if left a long time in contact with air, acquires a dark-yellow hue.

Mineral acids dissolve it, giving it a yellow color; alkalies, in contact with the air, turn it to a dark brown-yellow. Lime-water effects a similar change; acetate of lead occasions a white precipitate, which may be dried in a tube filled with nitrogen, without becoming perceptibly colored; but by exposure to the atmosphere, it acquires a yellow tint after a few hours.

On boiling a solution of quercitrin, it becomes turbid, and deposits a large quantity of small acicular crystals of quercitréin, less soluble in water, and which forms with hydrate of lead a beautiful golden-yellow quercitrate of lead.

These facts, therefore, show, says **Preisser**, that in the bark of the quercitron there is but one tinctorial principle, colorless in the heart of the wood, and which only passes into the yellow state—quercitréin—by the assimilation of oxygen. The brown matter is a mixture of the last-named principle and of tannin, or rather of quercitrate of lime tinged brown by altered tannin.

Quercitrin and quercitréin are for the greater part volatile. They contain no nitrogen.

The colorless quercitrate of lead consists of—

	At weight.	Centesimally. Theory.	Preisser.
64 Eqs. Carbon,	384	51·20	51·11
30 Eqs. Hydrogen,	30	4·00	3·99
28 Eqs. Oxygen,	224	29·87	29·84
2 Eqs. Oxide of lead,	112	14·93	15·06
1 Eq. Quercitrate of lead,	750	100·00	100·00

The formula of quercitrin is, therefore, $C_{32}\ H_{15}\ O_{14}$; and that of the lead compound 2 Pb O, $(C_{32}\ H_{15}\ O_{14})$.

Quercitréin was first obtained by **Chevreul** from a decoction of one part of the bark in five of water, which, after some days, deposited the yellow principle in a crystalline state. Quercitréin is either crystalline or pulverulent, yellow, inodorous, and slightly bitter. It is much less soluble in water than quercitrin, and dissolves in from four to five parts of alcohol; its solution is slightly acid, and after long exposure to air becomes reddish-brown; alkalies give it a greenish-yellow hue; it is entirely deprived of color by hydrated oxide of lead, which occasions in it a golden-yellow precipitate. Nitrate of silver causes a brown subsidence which soon decomposes, and the metal is reduced. With acetate of copper and chloride of tin, it gives a yellow, and with sesquisulphate of iron an olive-green deposit. A solution of alum brightens the color of a solution of quercitréin, and on adding an alkali there is a fine yellow precipitate. The yellow quercitrate of lead consists of—

	At. Weight.	Centesimally. Theory.	Preisser.
32 Eqs. Carbon,	192	41·46	41·53
15 Eqs. Hydrogen,	15	3·25	3·33
18 Eqs. Oxygen,	144	31·10	31·20
1 Eq. Oxide of lead,	112	24·19	24·94
1 Eq. Quercitrate of lead,	463	100·00	100·00

From which combination with oxide of lead, **Preisser** deduces the formula $C_{32}\ H_{15}\ O_{18}$ for *anhydrous quercitréin*, and represents it in its crystalline form as 2 HO, $C_{32}\ H_{15}\ O_{18}$.

Bark, as quercitron is commonly called, was for many years extensively used as a yellow dye, and almost completely superseded the use of fustic, both from its beauty and its cheapness; but it has been succeeded by the salts of lead and bichromate of potassa. It is still employed to give the ground on calico for certain browns, and for dyeing green upon light muslin cloth. Goods impregnated with iron, and passed through a decoction of bark, from its containing so much tannic acid, take a beautiful olive. When used for dyeing green, the mordant is acetate of alumina; but for yellow or brown, which is now only dyed upon yarn for particular purposes, chloride of tin is employed.

When bark is used for brown upon yarns, the following, according to **Napier**, is the mode of procedure:—The goods are dyed a yellow by being steeped in sumach, and then passed through the chloride of tin—spirits—out of which they are wrought in a boiling decoction of bark, *raised*, that is, the color brightened by an addition of spirits. The goods are washed from this, and afterwards passed through a mixture of logwood and Brazil-wood, according to the shade of brown required. **Thom** of Manchester was the first to observe, that amongst the coloring principles and bases there is an elective affinity, which, if not studied, will lead to several errors. The following was communicated by him to **Parnell**:—

The combinations of alumina, *et cetera*, with soluble coloring bodies, seem to be cases of true chemical combination, taking place in definite proportions, and under the influence of different degrees of attractive force for coloring principles. Thus, alumina has a stronger attraction for the principle of madder than for that of logwood, and a greater affinity for the latter than for that of quercitron. When a piece of cloth impregnated with alumina is immersed in a decoction of quercitron bark, it acquires a fast yellow hue; but if it is afterwards washed for some time, and kept in a hot infusion of logwood, the alumina parts with the color from the quercitron to combine with that of logwood, and the cloth becomes changed from yellow to purple. If it be next retained for a few hours in a hot infusion of madder, the coloring principle of logwood is separated, and the alumina unites with that of madder, the tint of the cloth altering from purple to red. The amount of alumina on the fibre does not appear to diminish while these substitutions are taking place.

The same law, says **Napier**, is applicable when the mordant is tin; so that when goods are dyed yellow, as previously described, by quercitron, and put into a hot solution of logwood and Brazil-wood, a quantity of the yellow is displaced by the coloring matters of the latter. Should the dyer fail to strike the proper tint at the first dip, and be necessitated to continue working in the logwood and Brazil-wood, there will certainly be a deficiency of yellow from this reaction.

A vegetal extract, bearing the name of flavin, was introduced a few years ago into the art as a substitute for quercitron bark, to which, for some purposes, it is said to be superior. The general impression among dyers and calico-printers is, that it is nothing more than the coloring principle of bark, extracted for the purpose of saving the expenses of the transport of the wood. The appellation under which it was imported seems to have been arbitrarily adopted; or rather, perhaps, was so selected as to mislead the consumer into the belief that it had totally different properties than the coloring matter of the wood from which it was actually manufactured.

The mode of using it in the dye-house is to dissolve it in hot water, with which it gives a sort of turbid solution. It should be employed when newly dissolved; for, if allowed to stand, it deposits a brownish-yellow mass, in consequence of its not being completely soluble. If boiled in distilled water until all the soluble matter is taken up, and the clear solution decanted, it soon yields a subsidence.

In order to have a good color by flavin, it must first be raised by an aluminous mordant. A yellow color dyed by it weakens gradually when a little sulphuric acid has been added; and what remains preserves its brilliancy by passing through alum, and in respect of this property differs from bark.

The quantity of coloring matter in flavin, compared with bark, is as sixteen to one, or, one ounce of the extract is equal to one pound of bark. A solution of it gives the following reactions:—Sesquisalts of iron produce olive-black, and the protosalts deep greenish-black precipitates; protosalts of tin give lemon-yellow, while the persalts occasion orange-yellow subsidences; alumina causes a rich yellow deposit; acids reduce the color of the solution, and alkalies deepen it, rendering it redder.

Mr. LEESHING found that the action of a little acid water upon bark at a boiling heat increased the dyeing properties to a very great extent, probably by rendering the color more soluble in water, and by this means enabling the dyer to obtain a much more concentrated solution—a property of great importance in many operations, especially for the calico-printer. He also found that some of the other vegetal yellow dyes were affected in the same manner by acids, and considered the whole so important as to induce him to secure the right of the discovery by a patent, an abstract of which is appended:

In a wooden tub, or in a leaden pan, holding about eight hundred gallons, place from four to five hundred gallons of water, and one hundredweight of sulphuric acid of 1·830 specific gravity, or two hundredweight of muriatic acid of 1·192 specific gravity, and five hundredweight of the drug intended for the operation—either quercitron bark, flavin, or weld, as the case may be—in a ground or finely-divided state. After the whole has been well mixed, steam is allowed to pass through the mixture by means of a leaden pipe, reaching with the one end nearly to the bottom of the tub, the other end being connected with a steam boiler. After the temperature has been raised to 212° Fahrenheit, the boiling is continued for about three-quarters of an hour or an hour longer, when the whole is run off into a wooden trough, and mixed with a further quantity of cold water—about twice as much as has been used for the boiling. When, after cooling, the solid matter has settled to the bottom, the acid liquor is run off from the trough, and the trough filled again with water, and the whole is stirred up. After decantation, the water is again removed in the same way, and renewed once more; and after the removal of this, the remainder is generally found sufficiently free from acid. It is now either thrown upon a suitable filter, or filled into bags, and allowed to drain for a time, after which it is subjected to pressure, in order to remove as much as possible of the adhering moisture. The material so obtained is now ready to be used either directly for drying it, or it is to be dried by artificial heat, not exceeding 212° Fahr., and preserved for the same purpose.

The treatment which has just been described may be modified so as to heat or boil the dye-stuffs, mentioned in the foregoing, with weak solutions of alkalies previously to the application of acids. In this case the patentee employs for five hundredweights of the dye-stuffs intended for operation, thirty pounds of crystallized carbonate of soda, or corresponding quantities of carbonate of potassa or ammonia, or of caustic soda, or potassa, or ammonia, and four hundred gallons of water. After having boiled this mixture for a quarter of an hour, one hundred and twenty-two pounds of sulphuric acid of 1·830 specific gravity, or two hundred and forty-four pounds of hydrochloric acid of 1·192 specific gravity, are added, and the whole is boiled for three-quarters of an hour longer, when it is run off, cooled, and treated in the same way as described before. The dye-stuffs prepared according to either of these modifications are called by the patentee, when obtained from quercitron bark, *quercitrin*, when obtained from flavin, *flavetin*, and that from weld, *luteolin*. They distinguish themselves from the original drugs by being free from those constituents, such as tannin and lime, which are known to interfere with their use in dyeing; but the coloring matters contained in those drugs have at the same time undergone a change, and acquired new properties, which are exhibited by their increased affinity for mordants, and their yielding brighter and much richer shades in dyeing; and, though much less soluble in either hot or cold water, they show themselves now much better adapted for those branches of dyeing, where the temperature has to be raised to boiling, than is the case with the original drugs.

Yellows are dyed by bark in the following manner:—Work through a solution of protochloride of tin, of the specific gravity of 2° Twaddell, for thirty minutes; wash out this, and then work for fifteen minutes in a decoction of bark kept at boiling heat; lift out the goods, and add to the bark solution half-pint of single chloride of tin; work the goods twenty minutes longer in this, and wash well in cold water. This gives a rich yellow. Three pounds of bark will dye ten pounds of calico or cotton yarn.

Dark shades of yellow are dyed in the same manner; but previously to working in the spirit or protochloride of tin, the cotton is steeped for six hours in a decoction of sumach, put in while hot, and allowed to cool, proceeding afterwards exactly as in the previous case, with the same quantity of stuff.

This last yellow, as has been already intimated, forms the basis for brown. After having dyed the goods yellow, they are washed, and then wrought in a decoction of three pounds Brazil-wood and one pound logwood; after fifteen minutes' working in this, there are added four ounces alum in solution; again wrought for fifteen minutes, and washed. These proportions will produce a very rich shade of brown, and any other variety of shade may be given by varying the proportions of the ingredients, and the depth of yellow as the ground.

A decoction of bark is also used for dyeing yellow upon silk. For five pounds of silk, work for half an hour in a solution of one pound of alum in one gallon of water; then wash from this in hot water, and afterwards work the goods in a decoction of two pounds of bark—the bark must be boiled in a bag—for half an hour; then add a pint of the alum solution, work ten minutes more, wash out, and finish. Or a very deep rich yellow will be given by proceeding in the same way; but instead of adding one pint of alum as raising, add two ounces by measure of single chloride of tin; work ten minutes, wash in water, then finish through a solution of white soap. Of course, different depths of yellow may be dyed upon silk by using different quantities of the bark and strengths of the mordant.

Working cotton for a few minutes in acetate of alumina at the specific gravity of 7° Twaddell, and then through a hot decoction of bark, produces a very good rich yellow, which soon changes, however, by exposure to the air; but for dyeing greens on light cotton goods, as muslins and gauze lenos, they are first dyed yellow by this means, using about two pounds of bark for ten pounds of cloth. After being dyed yellow, they are wrought in a solution of extract of indigo, the acid of which has been previously neutralized by carbonate of soda, forming a solution of indigo termed *chemic*. The yellow-dyed goods are wrought in this till the green is of sufficient depth; the length of time will, therefore, vary according to the strength of the chemic used.

This sort of green is only suitable for such of the above-mentioned goods as are to be finished in starch, the substance which chiefly contributes to give adhesion to the dye.

SAFFLOWER; *Bastard Saffron*, *Carthamus*.—This plant is called by botanists *Carthamus tinctorius*. It is a native of Egypt, and the warmer climates of Asia. It has been cultivated in Europe, near Alsace, and also around Lyons. The Chinese have long known its use, and produce from it their finest red. The color called by them *bing*, which is used by the Japanese ladies as a cosmetic, is made from it, and is kept in little porcelain cups similar to those retailed in this country as *pink saucers*.

It is obtained mostly from the East Indies and Turkey; the former is considered the best.

The *carthamus tinctorius* is an annual plant, with an upright, firm, smooth stem, of a light grey color. It grows to about three feet in length, when it divides into several branches, bearing leaves of an oval form, and edged with small spines. Each of the branches is terminated by a large flower-head, composed of several flowerets of a deep red color. The plant is propagated by seeds, which are sown early in spring. It is from the flower that the dye or coloring matter is obtained; and experience has taught that the richest color is produced when the flowers are gathered before being fully blown. When collected, they are dried in the shade, and carefully preserved from any moisture, which would deteriorate the color. Safflower is often found injured in this manner.

The plant is still cultivated in Egypt; and, according to HASSELQUIST, as soon as the flowers are collected they are pressed between two stones, so as to deprive them of a portion of their juice; they are then washed several times with spring water, which, in Egypt, generally contains a little common salt in solution. On being taken out of the water they are pressed between the hands, and then spread out on mats upon terraces, and allowed to dry slowly, being covered by mats during the day and exposed again at night. They are turned over from time to time, and when found to be properly dried are preserved for sale.

The use of this dye, says VOLNEY, in his Travels in Egypt, is probably as old as the time of the Tyrians, and the processes are still carried on to a perfection not unworthy of that people; but the workmen, jealous of the art, keep it an impenetrable secret.

The flower, or *safflower*, as it is termed in commerce, contains two coloring matters, one of which is yellow and very soluble in water, but is not used directly as a dye in any dyeing operation, although skins and leather, when steeped in it, become tinged of a beautiful and very permanent yellow, and even the hands of those working in it contract a stain of the same color, which is not easily removed.

This yellow coloring matter is separated as much as possible from the vegetal fibre, by washing in water upon a filter of cloth, so long as the water passing through the filter is colored; but even the most careful washing does not completely free the fibre from this yellow ingredient. The Editor thinks it probable that some of this yellow coloring matter is in combination with the red, and is not decomposed by water, but is set at liberty when the red is acted upon in a manner to be afterwards described; and hence the most carefully washed safflower, when *bled*, as the dyers term it—that is, when the red is extracted—contains in its solution a great quantity of the yellow also. The composition of the flower, as imported to this country, according to DUFOUR, is as follows:—

Red coloring matter,	0·05
Yellow color, with acetate of potassa and chloride of potassium,	1·42
Extractive matter, with sulphate lime and potassa,	2·68
Yellowish-green matter,	0·55
Resin,	0·03
Wax,	0·09
Woody fibre,	4·96
Alumina and lime,	0·05
Red oxide of iron,	1·02
Sand and particle of plant,	0·46
Moisture,	0·62
	11·93

From this analysis it will be seen that the quantity of coloring matter in safflower is very small. The red extract is found to have acid properties, and has been therefore called carthamic acid; it is insoluble in pure water, but dissolves readily in water containing alkaline carbonates, from which it is again precipitated by acids; it is also soluble in alcohol, imparting to that liquid a deep red when cold, but an orange tinge when hot: it is slightly soluble in ether.

M. **PREISSER** has discovered that carthamic acid loses a portion of its oxygen under the action of sulphide of hydrogen, and is then converted into colorless acid, to which he gives the name of carthamous acid. An excellent method of showing these effects is to wash a quantity of safflower in water, and then dissolve the red by carbonate of soda; this alkaline liquor is next precipitated by the hydrate of lead, which forms an insoluble lake of carthamate of lead. This salt is well washed, and then subjected to the action of sulphide of hydrogen, which converts the lead into a sulphide; the whole is filtered, and the liquor thus obtained has a yellow color, which, when evaporated, yields a mass of needle-shaped crystals, which constitute carthamous acid. This acid has a slightly bitter taste, is insoluble in water, dissolves to a small extent in alcohol, and when exposed to the air assumes a yellow color. It dissolves in sulphuric acid without change of color, and in hydrochloric and nitric acid with the aid of heat. When brought into contact with oxygen, along with some alkaline body, it undergoes a remarkable modification, and suddenly acquires a yellow color, which changes to a rose tint, and dissolves in alkaline solutions, from which, by the addition of an acid, it may be precipitated as carthamic acid, having absorbed oxygen. According to the above authority, M. **PREISSER**, carthamous acid is composed of—

	At. Weight.	Centesimally.
52 Eqs. Carbon,	312	76·10
18 Eqs. Hydrogen,	18	4·38
5 Eqs. Oxygen,	40	19·52
1 Eq. Carthamous acid,	370	100·00

and crystallizes with two atoms of water.

The composition of carthamic acid is given as follows:—

	At. Weight.	Centesimally.
52 Eqs. Carbon,	312	70·06
18 Eqs. Hydrogen,	18	4·01
7 Eqs. Oxygen,	56	25·03
1 Eq. Carthamic acid,	376	100·00

The yellow color washed from the safflower, when evaporated to the consistence of an extract, and then acted upon by alcohol, produces a soft yellow substance, having a saline taste; and when thus purified, the color is not so soluble in water. It has a slight acid reaction. The addition of acids renders the solution nearly colorless; alcohol, on the contrary, renders it dark; sesquichloride of iron gives a very deep tint; protochloride of tin and acetate of lead give a yellow precipitate; sulphate of copper gives a yellow-green precipitate.

The safflower of commerce varies considerably in its quality, both as to the quantity and brilliancy of color it produces. No chemical method of testing its quality which could be made available in the dye-house, has yet been discovered. The only reliable process is to dye with it a given quantity of cotton, as will be described afterwards in treating of the different processes adopted by dyers for that purpose.

The safflower is found in the market in dry hard cakes. To prepare it for dyeing, a quantity of these cakes are steeped in clean cold water. Hard or spring water is preferable for this purpose. A cover is put upon the top of the cakes, and is subjected to a gentle pressure to keep them under the water. They are allowed to lie in this condition till thoroughly wet and penetrated by the water, when the cakes expand and open up, under the influence of the moisture, into fine fibres. The whole is now removed by small quantities at a time, and placed upon a fine hair sieve, when water is passed through until it ceases to be colored yellow. The washings are allowed to flow away, and the red fibres are then placed into a vessel sufficiently large to hold a gallon of water for each pound of safflower. To this water is added from three to four ounces of carbonate of potassa or soda for every pound of safflower; the whole is well stirred, and the stirring repeated every half hour. After six or seven hours the safflower has lost its red color, and acquires a dun tint; the whole is again passed through a hair sieve; but on this occasion the liquor passing through is carefully preserved, as it contains the red coloring matter forming the dye; a little clean water is poured over every sieve-charge of the exhausted fibre, to wash out all coloring matter. The fibre is then pressed as dry as possible, and thrown away. The liquor has now a brownish-red color, and is ready to dye cotton—a process which is performed as follows:—

To the liquor, or to that portion of it which the experienced dyer knows to be required for the particular tint, as much acid is put as will not only neutralize the alkali used for extracting the red, but give a considerable acidity to the taste; sulphuric acid is generally used for this purpose. The cotton is then steeped in this liquor till all the red color is taken up by the cotton, which is known by a drop of the liquor held between the eye and the light being of a yellow color. It is scarcely necessary to remark, that the cotton must be kept well spread out, and in motion during the whole of the time it remains in the solution, in order to obtain an equal dye over all its parts. The cotton is now washed in clean spring water, and then finished or dried, after immersion in cold water containing in solution some cream of tartar. The color should not be exposed to sunshine or any vapor during drying, as it is easily affected by these influences, and should be dried in the cold or in a very dry heat.

It has been seen that sulphide of hydrogen converts the red carthamic acid which constitutes the dye into a white acid. It will therefore follow, that if the air of the apartment in which the cotton or other goods dyed by this substance is dried, have in it any sulphide of hydrogen—which is a very common ingredient in dye-works—the red produced by safflower will be destroyed.

It has been stated, that notwithstanding all the care that can be given to the washing of safflower some of the yellow remains, and is found in solution amongst the red; and also that animal tissues are stained by this yellow dye. Hence, when silk or woollen has to be dyed red, if the process were conducted in the same manner as with cotton, this yellow matter would affect the beauty of the dye. To avoid this, when silk or woollen is dyed red by safflower, the following process is adopted:—The color is first taken up by the cotton, as already stated, and the cotton washed from all yellow, and then it is put into water containing a little of an alkaline carbonate, and the red dissolved off. This red solution is that used for dyeing woollen and silk, which is done in the same manner as the cotton, only, with woollen, the solution is used hot.

There has been lately introduced an extract of safflower, which is a solution of carthamic acid, or rather that coloring matter held in suspension. Instead, therefore, of preparing the safflower from the cotton, as described, woollen and silk dyers use this extract, which is done by pouring a small quantity of it into water, adding a little acid—generally a little tartaric or citric acid—and then working the fibre in it till all the red is taken up.

The mode of testing the commercial value of safflower will now be apparent, and that it can only be done comparatively; namely, by taking the different samples to be tested along with a known quality, weighing an exact quantity of each, and treating them as has been described; then dyeing with each an exact quantity of the same kind of cotton, and comparing the depth of tint obtained.

The colors dyed by safflower are very bright, but they are very fugitive, giving way by the slightest alkaline action, and also by exposure to moist air.

A deep rose color will be produced upon ten pounds of cotton by four pounds of safflower. Prepare the safflower as just detailed, only adding to the liquor produced as much water as will suffice to work this quantity of cotton; then continue to work the cotton so long as there remains any red tint in the liquor. For a light pink, two pounds safflower will suffice, and for a deep crimson seven or eight pounds will be necessary: this last color will require several hours' working.

A rich scarlet may be produced by passing the cotton first through a strong solution of annotta—see page 570—until it is a deep orange, then dyeing with seven pounds of safflower in the same manner as the crimson: this produces the finest possible scarlet upon cotton.

A good pink may be dyed upon five pounds of silk by one pound of safflower, treating it as above described for dyeing silk. By using three pounds of safflower a good rose color is produced, but for this shade the silk should be previously dyed lavender by working it for a little in archil—see page 570—and then proceeded with for rose. A deeper shade may be obtained by using more safflower and a deeper bottom of lavender. Woollens are seldom dyed with safflower.

Napier mentions a fact, interesting in a philosophical point of view, as to the attraction of organic fibres for coloring matters in suspension; for the red color of safflower, when the acid is added, is held merely by suspension. If a large wide vessel be taken, filled with water, having in it a little carthamic acid, and a skein of cotton be suspended in the centre of the solution, in a few hours the cotton will have attracted all the coloring matter in the water, indicating thereby a distinct power of attraction exercised by the fibre, differing from mere capillary attraction, and also that there must have been a regular circulation of fluid through the whole mass, and also through the organic fibres of the cotton—a subject deserving of a much more lengthened investigation.

Saunders-Wood—more properly termed Santal or Sandal wood—is the wood of the *pterocarpus santalinus*, a native of the East Indies, growing chiefly on the Coromandel coast. It is a solid compact wood, and is imported in large billets. On the outside it appears of a dull muddy red, nearly black; within it is a bright red, but becomes brown by exposure. It is used always in a ground state, and is easily distinguished from Brazil-wood from its hardly imparting any color to boiling water.

Santal-wood contains about 16 per cent. of coloring matter, which is all soluble in alcohol. On evaporating this solution to dryness, the color remains mixed with a little resinous matter, which is purified, according to M. **Preisser**, by mixing the ethereal solution of this wood with oxide of lead, which forms a lake. The lead is afterwards separated by sulphide of hydrogen, and the santalin is obtained as a white crystalline powder by evaporation *in vacuo*. This powder, when exposed to the air, becomes red, especially if subjected to ebullition in water, or to the action of the alkalies. This red color is soluble in ether and alcohol, and, what is very singular, is also soluble in water, although in the wood it is very difficultly so.

If alcohol contains but a small portion in solution, the color is yellow, but if a large quantity, the solution is red. This solution thickens in the air like varnish. Acetic acid dissolves the color, and gives a red solution. It possesses an astringent taste, and colors the skin red.

One hundred parts of boiling oil of turpentine dissolve only 0·65 part of santalin. The same quantity of volatile oil of lavender, at the boiling point, dissolves two per cent. The aqueous solutions of potassa, soda, and ammonia dissolve it, and give it a violet-red color. The santalin may, according to M. **Pelletier**, be precipitated from these solutions without change, by the addition of an acid. The liquor, however, remains yellow, but gives a blue color by reflection.

Chloride of tin throws down a purple precipitate from the alcoholic solution; the salts of lead give a violet-colored one; the chloride of mercury, a scarlet one; the sulphate of iron, a deep violet; and the nitrate of silver, a reddish-brown. The salts of alumina do not precipitate it, unless they are added in the state of solution. By distillation it yields a small quantity of empyreumatic oil. Concentrated sulphuric acid blackens it. Nitric acid decomposes it, even when cold; by its action, a yellow resinous matter, a bitter soluble matter, and oxalic acid are obtained.

Santalin is composed of—

	At. weight.	Centesimally.
16 Eqs. Carbon,	96	26·6
8 Eqs. Hydrogen,	8	2·2
32 Eqs. Oxygen,	256	71·2
1 Eq. Santalin,	360	100·0

This differs from the composition of brazilin. It also differs from Brazil-wood in its dyeing properties, both as to the particular tint and its reaction with mordants, in which properties it more resembles barwood.

The coloring matter of the wood is more soluble in water containing in solution some astringent matters. Hence practical men generally add with the wood some sumach. Its use is mostly confined to woollen dyeing.

Sooranjee—a name given to the plant called by botanists *mornida citrifolia*—has been long and familiarly known as yielding one of the most extensively employed native Indian dyes. Professor **Anderson** of the Glasgow University has given this subject a complete investigation; and the following account of this interesting substance is taken from the excellent memoir by that chemist:—

The subject of these experiments was imported into Glasgow, some time since, under the name of sooranjee, with the intention of introducing it as a substitute for madder in the art of dyeing. For this purpose it was, on its arrival, submitted for trial to some of the most experienced and skilful calico-printers in Glasgow, all of whom concurred in declaring it not to be a dye at all, and to be totally destitute of useful applications. Professor **Balfour**, happening to hear of this circumstance, was so good as to obtain a quantity of the root, which enabled the professor to submit it to a chemical investigation.

Sooranjee is the root of the plant, and is imported cut up into pieces from one to four inches in length, and varying in diameter from half, down to nearly an eighth of an inch. On the small pieces the bark is thick, and forms a large proportion of the whole root, but on the larger fragments it is much thinner. Its external color is pale greyish-brown; but when broken across, it presents colors varying from fine yellow to brownish-red, and confined principally to the bark. The wood itself has only a slight yellowish shade, deepest in the centre, and scarcely apparent close to the bark; but it is colored dark-red by alkalies, indicating the presence of a certain quantity of coloring matter in it. The bark is readily detached, and its inner surface, as well as that of the wood, has a peculiar silvery appearance, most apparent on the large pieces, and almost entirely absent in the smaller. Boiled with water, it gives a wine-yellow decoction, and with alcohol a deep red tincture.

Morindin.—For the preparation of the coloring matter of sooranjee, to which he gave the name of *morindin*, Dr. **Anderson** at first attempted the use of boiling water, in which his preliminary experiments had shown it to be pretty soluble; he found, however, that this method was inapplicable, as the decoction contains a quantity of mucilaginous matter, which hinders the filtration of the fluid. The use of alkalies, in which the coloring matter is rapidly dissolved, likewise proved abortive, and recourse was finally had to alcohol, which succeeded perfectly. The bark of the root, separated from the woody portions and ground to fine powder, was boiled with six times its weight of rectified spirit, and the tincture filtered boiling hot. Its color was deep brownish-red, and on cooling it let fall the greater quantity of the coloring matter as a brown flocculent precipitate, containing the morindin, contaminated by another red coloring matter which exists in the root in small quantity only. A second decoction, with an equal quantity of spirit, gave a paler solution, from which morindin was deposited with a much smaller quantity of the red coloring matter. This treatment was repeated over and over again, as long as the tincture deposited anything on cooling; and every successive boiling produced it purer than the preceding, until at length, from the final decoctions, it made its appearance in the form of minute radiated crystals of a yellow color. By successive crystallizations from alcohol of 50 per cent., the red matter with which it was mixed was entirely removed, and the morindin obtained of a fine yellow color. It was still, however, impure, and contained a quantity of ash, amounting in one experiment to 0·47, in another to 0·32 per cent. The separation of this could not be effected by crystallizations from alcohol alone; but, after some trouble, it was completely removed by solution in alcohol slightly acidulated by hydrochloric acid, from which it crystallized in a state of purity.

Morindin is deposited from alcohol in minute needles, which, if the solution be dilute, make their appearance in radiated circles attached to the glass, and resembling in their arrangement the crystals of wavellite. They are extremely soft, and on being detached, collected on a filter and dried, mat together into a mass, presenting a rich sulphur-yellow color and satiny lustre. These crystals are sparingly soluble in cold alcohol, much more so in boiling spirit, especially if dilute; and the fluid on cooling is filled with a mass of bulky needles, which when dried shrink into a very small bulk. They are much less soluble in absolute alcohol, and totally insoluble in ether. Water dissolves morindin in the cold very slightly, although sufficiently to communicate a yellow color to the fluid; at the boiling temperature, however, it is readily taken up, and again deposited on cooling as a gelatinous mass, destitute of all traces of crystallization, which stops up the pores of the filter, and prevents the separation of the mother-liquor. It dissolves in solutions of the alkalies with a fine orange-red color. With concentrated sulphuric acid it gives a deep purple, which is violet in thin layers. After twenty-four hours' contact, the solution, on being diluted, deposited yellow flocks of the coloring matter in an altered condition, as it was now totally insoluble in cold water, and gave with ammonia a violet and not an orange solution. Nitric acid, specific gravity 1·38, dissolves morindin slowly in the cold with a deep brownish-red color. The application of heat immediately produces violent action, the brown color disappears, and nitrous acid fumes are evolved. The fluid, after long-continued boiling with the acid and neutralization with ammonia, gave no precipitate with salts of lime.

Solution of morindin gives, with subacetate of lead, a precipitate, depositing itself in crimson flocks, which are extremely unstable, and cannot be washed without losing coloring matter. With solutions of baryta, strontia, and lime, it gives bulky red precipitates, sparingly soluble in water. Sesquichloride of iron produces a dark-brown color, but no precipitate. When its ammoniacal solution is added to that of alum, the alumina precipitated carries down with it the morindin as a reddish lake; and when added to sesquichloride of iron, a brown precipitate is thrown down, which cannot be distinguished from pure sesquioxide of iron, but which contains morindin, as the supernatant fluid is colorless.

From analyses of morindin, the results were as follow:—

	At. Weight.	Centesimally.		
		Theory.	Anderson.	
28 Eqs. Carbon, ...	168 ..	55·44 ..	55·46 ..	55·40
15 Eqs. Hydrogen, ...	15 ..	4·95 ..	5·19 ..	5·03
15 Eqs. Oxygen, ...	120 ..	39·61 ..	39·35 ..	39·57
1 Eq. Morindin, ...	303 ..	100·00 ..	100·00 ..	100·00

The formula thus ascertained brings out an interesting relation between morindin and the coloring matters of madder, and more especially that one which is obtained by the sublimation of madder-purple. From his analysis of this substance, Schiel deduces the formula C_7 H_4 O_4. As this, however, is no more than the simplest expression of the analytical results, and as all the other madder coloring matters examined contain twenty-eight equivalents of carbon, one is justified in supposing its real constitution to be represented by quadruple of that formula, or H_{28} H_{16} O_{16}, which differs from that of morindin by a single equivalent of water only. The unsublimed madder-purple is also connected, though more remotely, with morindin, and differs only by containing five equivalents of hydrogen less, its formula according to Schiel being C_{28} H_{10} O_{15}.

This similarity, however, does not extend itself to their properties as dyes, in which respect they differ in a very remarkable manner. It has been already mentioned that the calico-printers had entirely failed in producing a color by means of sooranjee; and this Dr. Anderson fully confirmed as regards the common mordants. He digested morindin for a long time, in a gradually increasing heat, with small pieces of cloth mordanted with alumina and iron; but nothing attached itself, and the mordants, after boiling for a minute or two with soap, were found to be unchanged. Even with the root itself, alum mordant only acquired a slight reddish-grey shade, and iron became scarcely appreciably darker in color. The case was different, however, when cloth mordanted for Turkey-red was employed. Pieces of calico prepared for Turkey-red both by the old and new processes were obtained; and it was found that both acquired with morindin, in the course of a couple of hours, or even less, a dark brownish-red color, devoid of beauty, but perfectly fixed. These observations agree with the account given by Mr. Hunter of the method of dyeing with the *M. citrifolia* employed by the Hindoos. The cloth is first soaked in an imperfect soap, made by mixing the oil of the *Sesamum orientale* with soda-lie. After rinsing and drying, it is treated with an infusion of myrobalans—the astringent fruit of the *Terminalia chebula*—and exposed for four or five days in the sun. It is then steeped in solution of alum, squeezed, and again exposed for four or five days. On the other hand, the powdered roots of the *Morinda* are well rubbed with oil of sesamum, and mixed with the flowers of the *Lythrum fruticosum*—Roxburgh—or a corresponding quantity of *purwas*—the nut-gall of a species of *Mimosa.*—The whole is introduced along with the cotton into a large quantity of water, and kept over a gentle fire for three hours, when the temperature is brought to the boiling point. The red color so obtained is, according to Mr. Hunter, more prized for its durability than its beauty. This is simply a rude process of Turkey-red dyeing. He also mentions that, by means of iron mordant, a lasting purple or chocolate is obtained; but in this case the color is probably affected by the tannin of the astringent matters employed in the process.

Morindin is a true coloring matter, and is capable of attaching itself to common mordants. It gives with alumina a deep rose-red, and with iron violet and black; but the colors are not very stable, and it has a strong tendency to attach itself to the unmordanted parts of the cloth, and to degrade the white. Morindin, after treatment with sulphuric acid, is capable of attaching itself to ordinary mordants.

The discovery of a peculiar coloring matter, capable of fixing itself exclusively on Turkey-red mordant, is of interest, as establishing the existence of a peculiar class of dyes hitherto totally unsuspected, a class which may be extensive, and may yield important substances. It may serve also, in some respects, to clear up the *rationale* of the process of Turkey-red dyeing, which has long been a sort of opprobrium of chemistry. Although that process has been practised for a century in Europe, and has undergone a variety of improvements, no clear explanation of it was for a long time given; but it was supposed that, by the action of the dung, of which large quantities are employed, the cloth underwent a species of *animalisation*, as it was called, by which it acquired the property of receiving a finer and more brilliant color than could be attached to it by purely mineral mordants. Recent experiments have, however, shown that the oil, which is largely employed in the process, undergoes decomposition by long exposure to the air in contact with decomposing animal matter, and is converted into a sort of resinous matter, which constitutes the real mordant for Turkey-red. This has been pretty clearly made out by the experiments of Weissgerber. He found that when cloth had been treated with oil, so as to give when dyed a fine rose-red color, he could, by digestion with acetone, extract from it the altered oil; and as it was removed, the cloth gradually lost the power of attracting the coloring matter of madder, until, when it was entirely separated, the cloth passed through the dye without acquiring any color. On the other hand, he found that, by applying the substance extracted by acetone in sufficient quantity to cloth, he could obtain the richest and deepest colors with madder, without the addition of any other substance whatsoever. These observations receive additional confirmation from the experiments detailed in the present paper, as it must be sufficiently obvious that the dark-red color obtained on Turkey-red mordant with morindin, must be entirely irrespective of the alumina, on which that substance is incapable of fixing.

Dr. Anderson fully agrees with the opinion expressed by Persoz, that the use of alum mordant, which is at present always employed in Turkey-red dyeing, will be entirely abandoned so soon as calico-printers have learned the method of modifying at will the oil which they employ, so as to bring it at once into the state in which it acts as a mordant. Some steps have been made in this direction by making use of some chemical agents, as nitric acid and chloroxide of calcium, for the purpose of acting on the oil, but the improvements which have been effected stop far short of what will eventually be effected, when the system of pure empiricism, which has been all along employed in this particular process of dyeing, is abandoned, and the subject submitted to really scientific investigation. It is understood that M. CHEVREUL has entered upon the inquiry, and in his hands there is little doubt but that it will meet with a satisfactory solution.—*Transactions of the Royal Society of Edinburgh.*

SUMACH—*Rhus coriaria.*—This has been already referred to under FUSTET. It was long known as *young fustic*, and is still occasionally so named, from some kinds of it producing a yellow dye with aluminous and tin mordants, especially upon woollen fabrics. It is now seldom used directly as a dye, but is extensively employed as an auxiliary, in consequence of its containing large quantities of tannin and gallic acid; and has in many operations superseded the use of galls. There is considerable variety in the qualities of the sumach brought into this country, and the different kinds are distinguished by the names of the countries from which they are imported, such as Sicily sumach, Malaga sumach, *et cetera.* Each has qualities rendering it more suitable for certain uses than another. Sicily sumach has a fine greenish-yellow color, and is admirably suited for bright shades of red with Brazil wood. Malaga sumach has more of a fawn tint, and suits for deep colors, as black, brown, *et cetera.* So great is the difference between different sumachs, that, in some cases, it would require nearly fifty per cent. more of one than the other to produce the same effects. Decoctions of sumach should be used when newly made. If allowed to stand a few hours after cooling, fermentation begins in the solution. In this case, the yellow coloring matter is immediately destroyed, the tannin is converted into gallic acid, the decoction loses much of its dyeing property, and colors dyed with it in this state are neither so rich and deep, nor so permanent, as if dyed previous to fermentation commencing. Goods are often allowed to steep in the sumach until fermentation has proceeded to such an extent that the solution has a sirupy appearance, and is quite sour to the taste. This practice is reprehensible, producing a bad effect upon the colors afterwards dyed upon the goods.

As already stated, sumach is used principally as a base or bottom for giving depth or solidity to the colors. This will appear from the following details of the reactions in dyeing a black upon cotton:—The goods are immersed in a decoction of sumach at a boiling heat, and allowed to steep till cold. They are then lifted out, when they appear of a hazel color; after which they are passed through lime-water. This produces a deep green, which is very fugitive. From the lime-water they are removed direct to a solution of copperas, or iron liquor, the former being most generally used. This gives a deep heavy slate color, bordering on black. After washing from this, to remove any iron not combined with the color, the goods are then wrought in a decoction of logwood, which produces the rich black. Without the tannin of the sumach, the iron and logwood could not give a black of any degree of permanency.

If red is to be dyed, the goods from the sumach are steeped in a solution of chloride of tin; this produces, with the sumach, a rich yellow. After washing from the tin solution, the goods are wrought in a decoction of Brazil wood, which gives a rich red; but without the tannin of the sumach, the color produced by the tin and Brazil wood would be a very poor and fugitive red. As gallic acid is known not to have the same effect as tannin in producing these results, it will follow, if the tannin in the sumach is converted into gallic acid, by fermentation, the effects of the sumach will thus be destroyed to that extent to which tannin differs from gallic acid.

From these preliminary observations, practical readers will see the value of such investigations. The following is taken from an article by M. BARRESWEL, in the *Comptes Rendus:*—

When solutions of gallic or of tannic acid, which are colorless, and generally form colorless salts, or of the color of the bases, are poured into a solution of the sesquisulphate of iron, an intense blue precipitate is formed, which remains suspended in the liquid. This anomalous fact has frequently excited the attention of chemists, MM. BERZELIUS and CHEVREUL have even expressed some doubts respecting the simplicity of the reaction.

It has long been known that tannic and gallic acids do not precipitate the protosalts of iron when protected from contact with the atmosphere. BERZELIUS, CHEVREUL, and PERSOZ have, moreover, observed that when gallic acid or tannin is conveyed into a salt of the sesquioxide of iron, it is always reduced to the state of a protosalt. This fact is easily proved by adding to the blue solution produced by the sesquisulphate of iron in a solution of gallic acid, an excess of acetate of lead or of carbonate of lime, which precipitates the blue combination, and at the same time the sulphuric acid. A colorless liquid is separated by filtration, in which the presence of iron may be demonstrated in the state of protoxide.

These experiments are insufficient to explain this curious reaction. It is not improbable to admit, as MM. BERZELIUS and CHEVREUL have done *à priori*, that the oxygen combining with the gallic acid or the tannin converts them into a new acid of a blue color; but positive experiments were wanting to decide the point.

When a solution of tannin or of gallic acid is poured by drops into a solution of sesquisulphate of iron in excess, no blue coloring is obtained; if there is one produced, it is only momentary. Nor is there one formed with the same salt in minimum in presence of chlorine, nor with a protosalt of iron and gallic acid oxidized in various degrees by chlorine, by a salt of silver, or lastly, by the atmosphere in an alkaline solution.

When a solution of gallic acid in excess is conveyed into sesquisulphate of iron, and the liquid thrown down by acetate of lead, a blue paste is obtained, which, treated with oxalic acid, forms soluble oxalate of iron; the blue color disappears entirely, and is restored by acetate of soda. The solution of the oxalate, diluted very much with water, treated cautiously with ferrocyanide and ferricyanide of potassium and sulphide of hydrogen, presents all the characters of the salts of iron in the state of sesquioxide and protoxide.

It appears that the conclusion to be drawn from the above facts is, that if one starts with a protosalt of iron, it is requisite to add oxygen, and if sesquisalt be commenced with, some oxygen must be removed, in order to produce the blue compound, and that this compound contains the two oxides. In the first case, the protoxide of iron combines with the oxygen of the atmosphere; in the second, a portion of the oxygen of the sesquioxide destroys a corresponding portion of the gallic acid or of the tannin, converting it into a brown substance. This substance does not enter into the constitution of the new compound, which must be considered as a salt formed of tannin or gallic acid, and of an intermediate oxide of iron, probably of a blue color, the tint of which is slightly altered by this brown substance.

To prove, in the most evident manner, that the blue coloring is not to be ascribed to a blue acid, but to a particular oxide, BARRESWEL endeavored to obtain other blue salts with mineral acids—for instance, with sulphuric acid. For this purpose he prepared some mixtures, in variable proportions, of the protosulphate of iron and of the sesquisulphate, and to avoid an inevitable separation of the two salts from their different degrees of solubility, he removed *immediately* the water by adding to the solution concentrated sulphuric acid in large excess, taking care to produce as little heat as possible. In this manner a thick paste of a *deep blue* was obtained, the tint of which was more or less pure according to the proportions of the two salts of iron. He likewise produced a blue sulphate, but of very ephemerous existence, by evaporating rapidly a mixture of the two salts of iron; the blue tint appeared at the moment when the mass was nearly dry. On substituting phosphate of soda for the sulphuric acid, he obtained a deep-blue phosphate of iron and some sulphate of soda, which removed the water immediately. An endeavor was made, but without success, to prepare combinations with other salts. The hyposulphate of soda alone afforded an intense blue coloring, but of remarkable instability. This is not surprising; there are many instances in chemistry of bases which prefer combining with certain acids and refuse to unite with others; such, for instance, among others is the protoxide of copper.

The same chemist made numerous experiments to obtain the blue oxide in a free state, and succeeded several times, but under circumstances which he was not able to produce at will. It is, however, a well-known fact, that when a protosalt of iron is precipitated with ammonia in contact with the atmosphere, the white precipitate of the protoxide soon becomes green, passing first, however, through blue.

The impossibility of obtaining the blue sulphate of iron in a crystalline state, and of isolating the acid of the blue gallate compound, prevented BARRESWEL from having recourse to analysis in order to arrive at the formula for these intermediate salts. He was forced to proceed by synthesis, which he confesses is far from being accurate, and it was with some doubts that he published the results.

Of all the mixtures of protosulphate and persulphate which BARRESWEL experimented on, that which afforded the most pure blue with sulphuric and gallic acids, and with the phosphate of soda, contained precisely three equivalents of protosalt to two of the sesquisalt—proportions which correspond to the cyanide $Fe_7\ O_9$, prussian blue.

If he has thus rendered probable the existence of two intermediate oxides of iron, capable of forming salts, and of entering into the salts with their peculiar color, he will have thrown some light on the various tints produced by the different kinds of astringent substances, morphin, salicylic acid, and some other organic principles; and, likewise, on the production of violet-black, brown, and green tints, with red and yellow-coloring principles, in presence of salts of sesquioxide of iron. He convinced himself that all the yellow-coloring substances—for instance curcuma—do not produce green; that the red-coloring principles—among others aloetic acid—do not give a violet; and that when there is a production of green—as with the Persian berries and the quercitron—or of violet—as with madder, logwood, *et cetera*—the phenomena are identical with those which occur with tannin and gallic acid. These observations agree, moreover, perfectly with the suppositions of M. THENARD, with the facts published by M. KÖCHLIN-SCHOUCH, and by M. SCHLUMBERGER, and which M. STACKLER has found confirmed in his establishment, that the iron mordants should be at a fixed degree of oxidation to produce beautiful dyes.

Since this paper was given to the world, some of these views have been corroborated. The paper of Professor CALVERT upon this subject is so much to the point, and its practical bearing so important, that the Editor quotes it entire:—

PERSOZ, in his *Traité de l'impression des Tissus*—Vol. I., page 262—remarks, that it is desirable, as much for the interest of the manufacturer as for that of science, that it should be known positively whether it is gallic or tannic acid which plays the most important part in dyeing with gall-nuts. This statement of PERSOZ, together with the knowledge of the fact that the manufacturers of extracts of coloring matters, were prevented from preparing extracts of tannin masses, by the rapid change which these extracts undergo, induced the author to make the following researches, with the hope of throwing some light on the subject.

The first experiments were made with the view of ascertaining the action of gallic and tannic acids in the dyebeck. For this purpose, CALVERT dipped one hundred square inches of iron-mordanted cloth into baths composed of twenty grains of these acids, and one and a half pint of water; and the dyeing was allowed to go on in the cold for twenty-four hours. It was found that the gallic acid rapidly dyed the iron mordant, but the color soon disappeared, whilst with the tannic acid, although the black was slower in forming, it remained permanent. Similar trials were then repeated, but gradually raising the temperature of the bath during one and three quarter hours to 180° Fahr., and then for half an hour to 212°. The general results were similar, the only difference being, that the black at first formed with the gallic acid, more rapidly and completely disappeared than in the experiments done at natural temperature.

These facts led to the belief that the gallic acid acted as a reducing agent on the hydrate of sesquioxide of iron fixed in the cloth as a mordant. To substantiate this view, CALVERT took a portion of the liquor from the bath in which the dyeing process had been conducted, and on examination found it to contain a large quantity of protoxide of iron in solution; whilst, in the case of the tannic acid liquor, no reduction of the oxide of iron had taken place. He also added a small quantity of chloroxide of calcium to the above solution of gallate of protoxide of iron, which not only precipitated a certain quantity of the black gallate of iron, but the liquor gave a permanent black on a fresh piece of iron-mordanted calico, leaving no doubt that the chloroxide had maintained the iron of the mordant in the state of sesquioxide. A very important question now presented itself, namely, will the presence of a free acid increase the reducing power of gallic acid? To determine this point, a weak solution of persulphate of iron was mixed with some gallic acid, and it was found that in proportion to the excess of acid, so did the blue precipitate first formed rapidly disappear, leaving in the glass vessel a brown-tinted liquor, containing a salt of proto and sesquioxide of iron. It was also ascertained that the addition of a small quantity of weak hydrochloric, sulphuric, or oxalic acid, greatly increased the reducing action. If, on the contrary, an excess of pure hydrate of sesquioxide of iron was added to a solution of gallic acid, even after several days, the dark-blue precipitate at first produced remained permanent, and no protoxide of iron was produced in the solution. If heat, however, was applied to the mixture, protoxide of iron might be detected in the liquor.

These facts clearly show, that gallic acid cannot be employed as a dye when used in excess, or in presence of any other acid; whilst tannic acid placed in similar circumstances to the above described with gallic acid, does not reduce the sesquioxide of iron, either at natural temperatures, or under the influence of heat. The only circumstances in which the conversion of the hydrate of sesquioxide of iron into protoxide was remarked, were on the addition of large excesses of hydrochloric, sulphuric, or oxalic acids. CALVERT is inclined, therefore, to believe that, under the influence of a great excess of mineral acid, the tannic acid splits up into sugar and gallic acid, and the latter substance produces the reducing effect above described. These results seem to afford an explanation of the fact observed some years ago by M. J. GIRARDIN of Rouen, that, to obtain good blacks, a calcareous water is advantageous, a result which is probably due to the lime of the carbonate neutralizing the gallic acid existing in the tanning matter, and so preventing it from exerting its reducing action on the iron mordant, which would interfere with the dyeing properties of its tannic acid.

Professor CALVERT was also anxious to ascertain the difference of the action of gallic and tannic acids on alumina. He accordingly took two pieces of calico, of one hundred square inches each, previously mordanted with alumina, aged and dunged, and placed them in separate baths, one of which contained twenty grains of gallic acid, and the other twenty grains of tannic acid; and during two and a quarter hours gradually carried the whole to the boiling point. These pieces were then taken out, washed in distilled water, and subsequently dyed with madder. It was found that the piece which had been in the gallic acid bath was almost colorless, while that from the tannic acid had acquired a deep red tint. The same results were obtained on dyeing a piece of calico, mordanted with alumina, in a bath composed of thirty fluid ounces water, twelve grains peachwood, and eight grains garancin, together with twenty grains tannic, or twenty grains of gallic acid. To leave no doubt as to the true action of these acids on alumina, pure hydrate of alumina was introduced into two tubes, with a solution of each of them; and after a few days' contact, it was found, on examining the supernatant fluids, that the gallic acid alone had dissolved alumina, the tannic acid not having acted at all, so that the latter may be considered, if not a neutral substance, at all events a very feeble acid.

CALVERT also attempted to obtain reds and blacks with an extract of sumach which had been kept some time, but failed, owing no doubt to the transformation of its tannin into gallic acid, as the results obtained were identical to those furnished by the above free acids. This rapid transformation of tannin into gallic acid in the extract of sumach is remarkable, when it is remembered that it takes only a few weeks or months in the case of the extract, whilst it requires years when the tannin is confined in the plant. These differences are no doubt due to the presence of water, which facilitates chemical actions. This rapid deterioration of tanning matters in the form of extract, is the reason why their substitution for the solid substances themselves has not been adopted by the silk dyers or tanners. It was therefore deemed advisable to make a series of experiments, in the hope of discovering a substance which would act as an antiseptic to this peculiar fermentation, for the researches of Messrs. DELAROQUE and ROBIQUET, junior, have clearly shown that tannin is transformed into gallic acid and a substance resembling sugar, under the influence of a peculiar ferment called pectase.

CALVERT'S investigations led him to discover three substances which possess the property of preserving from fermentation tanning extracts having a specific gravity 1·250, and as, doubtless, the employment of these substances will facilitate manufactures and cheapen production, he does not hesitate to publish them. They are chloride of lime, bichloride of mercury, but especially carbolic acid; and to show the efficiency of this acid, it may be added, that an extract of *sumach*, which was mixed with a few per cent. of this acid, was perfectly sound twelve months after being mixed. The first two substances answer very well, but the last has the great advantage of not interfering with the general applications of the extract of tanning matters.

The remarkable power of dissolving the hydrates of oxides of iron and aluminum possessed by gallic acid, induced Professor CALVERT to try its action, as well as that of tannic, on metallic iron. For this purpose, one thousand grains water, twenty-five grains acid, and one hundred grains iron-wire were introduced into tubes, so arranged as to convey the gases evolved to the pneumatic trough, care being taken to exclude all air. After a few days, it was found that several cubic inches of gas had been given off from the gallic acid tube, which, on testing, proved to be nearly pure hydrogen, whilst the liquor remained colorless, and only assumed a slight blackish-blue tint when exposed to the air. The iron, on being taken out, was carefully dried and weighed, and found to have lost 1·4 grains. Therefore, gallic acid has the property of dissolving iron. It was also observed, that in the case of the tannic acid, no gas was evolved, neither was iron dissolved; although the solution had assumed a slight purple tinge, which was attributed to some trace of oxide produced on the bright surface of the wire during its weighing. A similar series of experiments was also tried, substituting for the one thousand grains water, one thousand grains of a solution of sugar, having a specific gravity of 1·090; and it was observed, that although gallic acid acted in the way above described, tannic acid on the contrary, under the influence of the sugar, attacked the iron and gave a bulky dirty purple precipitate. Professor CALVERT regrets that he had not time to examine the nature of this action, neither the peculiar compound formed by the oxidation of the gallic acid, when brought in contact with an acid persalt of iron; but he proposes, when circumstances permit, to return to this subject.

In conclusion, from the facts contained in this paper, there can be no doubt that tannic acid is the constituent of tanning substances which produce blacks with iron mordants. 2. That the reason why gallic acid produces no black dye is, that it reduces the sesquioxide of iron of the mordant, forming a colorless and soluble gallate of protoxide of iron. 3. That gallic acid has the property of dissolving hydrate of alumina, and also of separating alumina mordant from the cloth on which it is fixed. 4. That the reason why extracts of tanning matters lose their dyeing properties is, that the tannin is transformed into gallic acid. 5. That gallic acid possesses the property of dissolving iron, and thus lays claim to the character of a true acid, whilst tannin, not having this action, appears to be in reality a neutral substance. 6. That carbolic acid possesses the property of preventing the tannin fermentation, or the conversion of tannin into gallic acid and sugar, or a similar substance, under the influence of a peculiar ferment called pectase.—*Edinburgh New Philosophical Journal.*

Allied to sumach are several other vegetal matters that contain tannin, and have been from time to time introduced into the dye-house as substitutes for sumach. Among these are the *Valonia nuts*, as the cups of the acorn from the Valonia oak are termed; they are imported in great quantity, but are inferior to sumach for the general purposes of the dye-house. For some objects, however, especially for dyeing a deep rich and permanent black upon silk for hats, the Valonia nut is in great use.

Divi divi, or *libi davi*, is another vegetal that has been tried instead of sumach, but not with success, being but poor in tannin.

Myrobalans—the fruit of a tree which grows in India, and is much used by the Hindoos as a substitute for galls—has been imported into this country for a similar object; but although it contains much of the properties of galls and sumach, and is occasionally used in their stead, it has not yet succeeded in superseding sumach.

There are many other vegetal substances that contain tannin, and which may be used in virtue of that property, and many of them have some distinctive and characteristic qualities of a different kind, which may render them useful for some particular purposes; but for general use in dyeing, nothing has yet been found capable of superseding sumach.

TURMERIC.—Turmeric, or Indian saffron, is a yellow dye obtained from the roots of *Curcuma longa.* This plant is indigenous to the East Indies and other parts of Asia, and to Madagascar. It has been cultivated with some success in Tobago, and samples from that island have been found superior to that usually imported from India. Our supplies are brought from the East Indies, China, and Java; of these, the Chinese turmeric is the best.

The roots of the *curcuma longa* spread far into the ground; they are long and succulent, and about half an inch in thickness. These roots are externally of a color inclining to grey, but internally of a deep yellow color; they are reduced to powder previous to being employed as a dye. The composition of this root, according to JOHN, is in one hundred parts:—

Yellowish volatile oil,	1
Yellowish brown resin,	10 to 11
Brown extractive matter with dyeing properties,	11 to 12
Gummy matter,	14
Matter soluble in alkalies, including earthy salts,	57
Moisture, loss, &c.,	7 to 5
	100

Cold water dissolves a little coloring matter of a yellowish tint; hot water takes up a larger quantity; but the whole coloring matter of this dye does not seem soluble in water.

Alcohol becomes yellow, and dissolves, besides the color, much of the resinous matter. Sulphuric, nitric, and hydrochloric acids, in their concentrated state, give the alcoholic solution of this matter a crimson-red color; nitrate of lead, a clear yellow; chloride of tin, yellow; salts of iron, a brown color, but no precipitate.

The coloring principle of the curcuma is obtained by macerating the powdered root in boiling water, until the liquid ceases to acquire any further tint. The residue is then to be boiled in alcohol. The greater part of the coloring matter is thus dissolved, but it is impossible to extract it completely, and the curcuma powder always remains more or less colored.

The filtered solution has a reddish-brown shade; it furnishes, by evaporation, a brown mass, which contains some extractive matters, and traces of chloride of calcium. These latter substances are left behind on treating the residue with ether, the coloring principle alone being dissolved, which may be obtained in a solid form by evaporation. The matter thus obtained is not, however, pure; to free it of all admixture, it must be dissolved anew in alcohol, and subsequently acted on by an alcoholic solution of acetate of lead. There is immediately formed a red precipitate, composed of the coloring matter, and of protoxide of lead. This deposit, having been washed and dried, is to be freely diluted with water, through which a current of sulphide of hydrogen should be passed, until all the lead becomes precipitated. The powder is now to be carefully washed, dried, and treated with boiling ether, which dissolves the curcumin, and leaves behind the sulphide of lead.

On slowly evaporating the ether, the curcumin is deposited in thin, transparent, and inodorous layers. When reduced to a fine powder, it is of a rich yellow color; indeed, the finer the powder, the brighter is found to be its tint. When in thin layers, it appears of a cinnamon-red; viewed against the light, it presents a deep red aspect.

By this proceeding, about half an ounce of curcumin is obtained from the pound of the root. By exposing it to the rays of the sun, it quickly loses its intense color, and gradually becomes of a yellowish-white.

The mean calculation of four analyses of curcumin, prepared in the foregoing manner, gave—

Carbon,	69·5
Hydrogen,	7·4
Oxygen,	23·1
	100·0

The dilute acids do not dissolve curcumin, but concentrated acids possess this property.

As might be anticipated from the above chemical reactions, and especially the effects of air upon the coloring matter of turmeric, the dye produced by this substance is very fugitive; it fades rapidly in the air; and, there being no proper mordant for it, its use as a dye must be very limited. Indeed, it is not now used except as a *topping*, to finish up and give a certain tint, which, however, only serves the emergency, and is not permanent. The rapid action of alkaline matters upon it, makes it a useful reagent for testing the presence of alkaline matters in solutions. Paper dyed yellow by turmeric, and preserved in the dark, will be rendered brown by the slightest alkalinity in water, and is, therefore, used for this purpose, under the name of test-paper.

WELD or **WOLD** is a biennial plant, called by botanists, *Reseda luteola*. This plant is well known throughout Europe, and is indigenous to England; it is found growing wild in many parts of the country, and is also cultivated for its coloring produce in several counties of England, such as Kent, Herefordshire, and near Doncaster, in Yorkshire. It is very extensively cultivated around Paris, and in other parts of France. The plant, after being gathered, is carefully dried, and tied up in bundles, in which state it is sold to the dyer. When boiled, it gives out its color easily to water, producing a beautiful greenish-yellow hue, and giving the following reactions with reagents:—

Alkalies	change it to golden-yellow.
Acids	deepen the color, rendering the solution muddy.
Alum	a yellow precipitate.
Tin salts	a yellow precipitate.
Acetate of lead	a yellow precipitate.
Sulphate of iron	olive color.
Chlorine	brightens the color.
Acetate of copper	greenish-red.

The solution has a peculiar odor and a sweetish-bitter taste, and slightly reddens litmus paper.

The coloring matter of this vegetal has been called *Luteolein*, and has been examined by M. CHEVREUL and M. PREISSER. It may be obtained in needle-shaped crystals by sublimation, but the latter chemist obtained it by making a strong decoction of the weld, which was of a clear yellow color, and deposited on cooling a multitude of small flakes of a yellowish-white tint.

If this liquid be boiled in a small quantity of chromic acid, on cooling, a large quantity of flakes of a golden-yellow color, similar to iodide of lead, that brighten by keeping for a short time in contact with air, are produced: this yellow matter is luteolein; it is presented first as white scales, and is soluble in water—more so in hot than cold—also in alcohol and ether; it has a sweetish taste, leaving a bitterness behind; it is volatile; its reaction upon litmus paper is decidedly acid.

Sulphuric acid dissolves it, producing a clear-colored solution; nitric acid, cold, acts in the same manner, but if heated, it is decomposed.

Sulphate of iron gives a precipitate of a greenish-yellow tint, which darkens by the air to an olive-brown; acetate of lead gives a white precipitate, which turns yellow by exposure.

Caustic alkalies give a deep yellow color to the solution at first, but afterwards the color is all deposited as a yellow precipitate. Baryta, strontia, and lime behave in the same way. Weld also contains tannin, which causes a change in the solution when it is allowed to stand exposed to the air.

The chemical properties of this dye have some resemblance to those of quercitrin; but it differs much from that substance in its dyeing qualities. It is used as a species of fermenting agent in certain kinds of blue vats, for the deoxidizing of the indigo or woad. It is seldom used for dyeing of cotton; and although, with an alum mordant, it gives a very fine yellow on that fabric, the yellow is very fugitive, giving way rapidly in the air. It is used, however, for dyeing yellows upon silk, to which it gives a yellow of a very fine tint.

The following process with the quantities mentioned will produce a rich yellow upon five pounds of silk:—Work the silk for an hour in a solution of alum of the strength of one pound to the gallon of water; wash from this in warm water; boil two pounds of weld for an hour in as much water as will serve to work the silk in easily; strain the liquor through a fine hair sieve; then work the silk in it for half an hour; add one pint of the alum solution; return the silk and work ten minutes longer, and wash out. Different depths of yellow can be dyed by varying the quantity of weld; and by adding to the weld a small quantity of a solution of annotta, amber and straw tints are produced.

WOAD—*Isatis sativa*—is a plant known and used for the purposes of dyeing from the earliest time. The ancient Britons, when invaded by the Romans, are described as having their bodies stained with the colorous matter of this plant. It is cultivated in the Azores and the Canary Islands, in Italy, in Switzerland, in parts of Germany, Sweden, and in various districts of France. It is likewise indigenous to England, and is still cultivated in Lancashire. For many centuries it was a most important branch of British industry, as has been repeatedly referred to both in the historical remarks and elsewhere. It is still used as a dye for blue in woollen and silk stuffs, often, however, accompanied with indigo, the coloring matters of these substances being similar. A superior quality of this dye, which is principally produced in the South of France, is known in commerce by the name of *Pastel*. The *Isatis sativa* is a biennial plant, having a large woody root, which penetrates deep into the ground; the stem is from three to four feet high, and about half an inch thick, divided into several branches, which are loaded with many leaves of a lurid green color. Three or four crops are usually obtained in one year. The plants are mowed with a scythe, and, as soon as collected, are washed in a stream of water and dried in the sun. This must be rapidly done, otherwise the woad will be impaired in quality. When dried, it is conveyed to a mill and ground into a smooth paste, which is laid in heaps, pressed close together, and covered to protect them from rain. If any crack appear in these heaps, care is taken to unite them, as that would also impair the quality of the woad. After remaining for a fortnight in heaps, the whole is rubbed together and formed into solid balls, which are pressed into a compact substance in wooden moulds and dried. Good balls are distinguished by their superior weight, and by having a violet color within. These balls are further prepared for dyeing, by being beaten with wooden mallets on a stone floor until they are reduced to a coarse powder, which is then heaped up in the middle of the apartment and moistened with water. Fermentation arises, and after about twelve days it is pretty well dried by being turned over, and then it is made into a heap for the use of the dyer.

According to CHEVREUL, when the leaves of the plant are subjected to the action of the press, a residue of a ligneous nature, and a juice, holding in suspension sundry matters which give it a dull appearance, are obtained. Thrown on a filter, it leaves a greenish matter, or fecula, which is formed of chlorophyl, wax, indigo-blue, and a nitrogenous substance. The clear liquid, after passing through the filter, contains a nitrogenous body, part of which only is coagulable by heat; a red matter, resulting from the union of the blue color with an acid; a yellow principle; gummy matter; sugar; a fixed organic acid; free acetic acid, and acetate of ammonia; odorous and volatile principles, the latter having the odor of osmazom; citrate of lime; sulphates of lime and potassa; phosphate of lime, magnesia, iron, and manganese; nitrate of potassa; and chloride of potassium.

CHEVREUL has not discovered in these products any body possessed of the power of seizing upon oxygen in an energetic manner, and which would explain the action of the pastel in the indigo vat. Still, it cannot be doubted that the principles furnished by this matter intervene, to a certain extent, as combustibles, and that at least a part of their effect must be referred to this mode of action. The indigo should itself be selected with care. The Guatemala variety is preferred for the urinary, or Indian, and the Bengal product for the pastel vat.

WONGSHY.—In the *Journ. für Prakt Chem.*, for December, 1849, appeared an article by W. STEIN upon a new yellow coloring matter, which had come under his notice. An excellent translation of this appeared in the *Chemical Gazette*, from which the Editor makes the following extracts, hoping they may be found of use to the practical dyer.

STEIN says—Towards the end of last year, a new material for dyeing yellow, called *wongshy*, was exported on experiment from Batavia to Hamburg, a sample of which was obtained from M. VOLLSACK, merchant. Whether it has hitherto been applied as a dyeing material, and with what results, could not be ascertained. The following notice, therefore, will probably not be without interest.

The new dyeing material consists of the seed-vessels of a plant, which, according to information from M. REICHENBACH, belongs to the family of the Gentianeæ. The form of the unilocular capsules is longish-ovate, drawn out to a point next the end of the peduncle, and crowned upon the opposite and more obtuse one with the dried six-lobed calyx. They vary in size; but on an average their length is 1·5 to 2 inches, and the diameter at the thickest part 0·5; the color is not uniformly reddish-yellow, but at some places darker, at others lighter. The surface is more or less irregularly waved with six to eight longitudinal ribs. The odor resembles saffron, and subsequently honey. The shell is pretty hard and brittle, but becomes quickly mucilaginous when chewed, imparting a yellow color to the saliva, with a slightly bitter taste; it swells up considerably in water. Inside the capsules there are a number of dark reddish-yellow seeds—in one specimen one hundred and eight were counted; they are not attached to the sides, but are imbedded in a hardened pulp, and so connected one with the other. These seeds are tolerably hard, soften but slowly when chewed, have no particular taste, but after some time produce at the point of the tongue a slight but peculiar sourish-sweet pungency, resembling the action of Paraguay rue. The pulp, on the other hand, cementing them together has a strong bitter taste, which is particularly perceptible at the back part of the palate.

The wongshy, especially when pounded, readily gives up to water, both at the usual temperature as well as on boiling, a coloring principle, which possesses such an enormous divisibility that two parts of the pounded capsules furnish one hundred and twenty-eight parts of a liquid, which, placed in a cylindrical vessel of white glass with a diameter of three inches, still appears of a bright wine-yellow color. The concentrated extract is very mucilaginous, and has a fiery red color, which on large dilution passes into a golden yellow, the red disappearing.

Alcohol, both absolute and of 0·863 specific gravity, when digested with the pounded fruit, acquires a fiery red color, which on dilution also changes to a golden color.

When digested with ether at the ordinary temperature, it assumes a wine-yellow or brownish-yellow color, and leaves on evaporation a thick yellowish-brown oil, which possesses the odor of the fruit, a mild slightly bitter taste, deposits at 32° a small quantity of a solid fat, and does not become thick when shaken with subnitrate of mercury even after long standing, and consequently belongs to the drying oils.

The aqueous extract gelatinizes on the addition of alcohol, and the yellowish gelatin may be obtained perfectly colorless by washing with alcohol. The solution in water is not precipitated by acids; caustic soda produces a gelatinous precipitate only when in excess; added in small quantity, the liquid remains clear, but upon the addition of an acid deposits gelatinous flakes. Carbonate of potassa acts in a similar manner, with this difference, that an excess causes the liquid to become thick only after a much longer time, and that acids produce but a small flocculent precipitate. The solution is so completely precipitated by barytic water, that the liquid filtered from the precipitate, on evaporation upon platinum and ignition of the residue, does not show any trace of organic matter. Lime-water causes a similar separation, and acetate of lead produces a gelatinous precipitate.

A solution of gelatin produces in the aqueous extract a trace of a precipitate arising from tannin.

Protochloride of tin produces no change at the ordinary temperature, or after a long time; on boiling, a dark orange-colored precipitate results.

Acetate of lead produces no change.

Basic acetate of lead causes a turbidness at the ordinary temperature, and an orange-colored precipitate on boiling.

Protosulphate of iron changes the color into a dark brownish-yellow, without, however, a precipitate resulting either in the cold or on ebullition.

Alum, acetate of alumina, and acetate of zinc produce yellow precipitates only on boiling.

Barytic water causes a yellow precipitate at the ordinary temperature, which on boiling acquires a reddish tint.

Lime-water gave a pure yellow precipitate; solutions of gypsum and chloride of calcium are not precipitated by it even on boiling; well-water, with a considerable amount of carbonate of lime, does not precipitate the coloring principle even with the assistance of heat; it is consequently not able to decompose the combinations of lime with acids.

To ascertain the value of the wongshy coloring matter for the purposes of dyeing, one part of the pounded capsules was digested for twelve hours with twenty parts of lukewarm water, being frequently stirred, and the liquid then strained. The coloring matter is most quickly extracted in this manner, without its becoming gelatinous from the formation of paste, as would happen were the liquid boiled. Properly prepared samples of woollen cloth, some without any mordant, others mordanted with alum, protochloride of tin, acetate of alumina, and basic acetate of lead, were dyed with this extract at a temperature of about 104° Fahr.; the color does not turn out so pure at a higher temperature. The unmordanted cloth was dyed a beautiful and uniform orange color by one immersion; of the mordanted samples, those with alum and acetate of alumina were better than those with protochloride of tin; the least satisfactory was that in which basic acetate of lead had been used as mordant. The tone of the color was not altered by the three first mordants, but it was less intense, and the stuffs were not uniformly penetrated by the coloring matter. However, the samples with alum mordant gave perfectly satisfactory results after a second immersion. The coloring matter likewise combines readily and uniformly with silk, communicating to it a very glowing golden color, so that in this case also it is preferable not to have recourse to mordants. Cotton, as was to be expected, can only be dyed with the assistance of mordants, and the best results appeared to be obtained with tin mordants; the color was orange, of a very agreeable tint.

The color, both upon wool, silk, and cotton, resists soap perfectly; but alkalies give it a yellow, acids and tin salt, a red tint. By this behavior it differs from the color of annotta, with which, as will subsequently be seen, it possesses in other respects great resemblance —a resemblance which unfortunately exists as regards the action of light. When exposed to light, the color very soon fades upon cotton, less quickly upon wool; and in this case it is more permanent upon the unmordanted samples. It resists the light longest upon silk; and in this respect, when compared with the other known yellow colors, may be reckoned among the best.

STEIN obtained a beautiful yellow, with a faint tint of red, by mordanting the woollen cloth with lime-water, and immersion in the boiling vat; it resists the soap perfectly, and the action of light much better than the orange. It is altered in a similar manner to the orange, by alkalies, acids, and tin salt, only less. Several very beautiful shades of yellow may be obtained by adding pearlash or caustic potassa to the dye, and immersing the unmordanted fabric at the ordinary temperature. The union of the color with the fibre takes place very quickly and very uniformly. By the addition of one part pearlash to thirty parts dye liquor, a yellow was obtained with a remarkable glow from a slight admixture of red. By the addition of twice the quantity of pearlash, a lively yellow, with a faint tint of green, was obtained. A still larger amount of pearlash cannot be used, as it renders the color dull and impure. With caustic potassa, instead of pearlash, STEIN obtained in the first place a pure brilliant yellow, with less red than with the pearlash; in the latter case, a beautiful canary-yellow with a shade of green. Ammonia acts in the same manner, but the color, under all circumstances, contains more red. The color also appears of a somewhat different shade when the fabrics are first immersed in the dye liquor, and then, after being washed, placed in an alkaline bath.

In the case of silk and cotton, the effect of alkalies is similar, but less apparent, because the silk and cotton fibres imbibe less of the coloring substance than those of wool.

That this color resists the soap is self-evident; but it also suffers less from the action of light than the orange, and when fabrics so dyed are passed through an acetic or hydrochloric acid bath, a brilliant aurora color is obtained. This interesting behavior, which the wongshy coloring matter has in common with that of annotta, is explained by the chemical character of the former, which is a weak acid; it combines with the alkalies, and with the alkaline earths, as is evident by the precipitation with baryta and lime-water. Its combinations with the former possess a pure yellow color, and are decomposed by stronger acids, when the liberated coloring matter separates of a brilliant vermillion color. But the coloring matter thus separated is no longer the same as that which was originally contained in the aqueous solution, for it is now perfectly insoluble in water, and is only dissolved in small quantity, and of a golden-yellow color, by absolute alcohol, ether, and spirit of 0·863 specific gravity. In the moist state it has a vermillion color; when dry and in the purest state, it is brown-red, like ratanhia extract, and is easily reduced to powder; but if it still contains sugar and fat, it has a beautiful yellowish-red color in thick layers, whilst in thin layers it is yellow and transparent, and becomes moist in the air. On heating the pure substance upon platinum, at first yellow vapor is given off, and at some spots the color becomes pure yellow; it subsequently turns black, fuses, and chars. The residual cinder is difficult to burn; the yellow vapors condense, when the experiment is made in a glass tube, into yellow oily drops. Concentrated sulphuric acid renders it scarcely perceptibly blue, and the acid acquires the same color, which quickly passes into violet and brownish-red, whilst the coloring matter slowly dissolves. Water separates from this solution a dirty yellowish-grey flocculent substance.

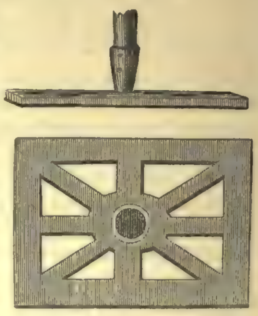
The reaction of the wongshy coloring matter which has just been mentioned, has no resemblance with the reaction of sulphuric acid upon annotta, for the liquid never acquires a pure blue color, as is the case with annotta, but is violet from the first, and only for a minute.

It dissolves readily in caustic ammonia and caustic soda with a golden-yellow color.

Vats, their Construction and Working.—A solid dye of indigo-blue is given to wool by plunging it into an alkaline solution of indigo-white, and then exposing it to contact with the air. The solution of indigo-white is prepared in a vessel usually from eight to nine feet in depth, and six to seven feet in diameter, which should be made of wood or copper, and always bears the name of *vat*. This size is very convenient for the requisite manipulations, and presents a large volume of water, which, when once heated, is capable of preserving a high temperature for a long time. These vats are covered with wooden lids, divided into two or three equal segments, covered over with thick blankets. Without this precaution, the bath would be more or less exposed to the atmosphere, and a portion of the indigo, absorbing oxygen, would be precipitated. There would also be a great waste of heat.

A most necessary operation, and one of frequent recurrence, consists in agitating the deposit of vegetal and coloring matter which is formed in the vat, and intimately mixing it in the bath. For this purpose a utensil, called a *rake*, which is sometimes formed of a strong square piece of wood, set on a long handle, is employed. In this country it is generally made of iron with a wooden handle, as shown in Fig. 350, which exhibits a side view and also the flat piece detached. The workman takes hold of the handle with both hands, and, dipping the flat surface into the subsidence at the bottom of the vessel, he quickly draws it up until it nearly reaches the surface, when, giving it a gentle shake, he discharges the matter again through the whole liquor of the bath. This manœuvre is repeated until the whole of the deposit seems to be removed from the bottom of the vessel. Before the tissue is dipped into the dye-bath, it should be soaked in a copper full of tepid water; it is then to be hung up and beaten with sticks. In this state it is plunged into the vat, and thus introduces less air into the bath, while the fibre is more uniformly penetrated by the indigo solution. The cloth is now kept in a depth of from two to three feet below the surface of the liquid, by means of an open bag, or piece of network, fixed in the interior of an iron ring, which is suspended by cords, and fixed to the outside of the vat by means of two small iron hooks; the bag is thus drawn backwards and forwards without permitting it to come in contact with the air. When this operation has been continued for a sufficient length of time, the cloth is wrung, and hung up to dry.

Fig. 350.



Flock wool, when dyed, is also enclosed in a fine net, which prevents the least particle from escaping, and which is fixed in the bath in the same way as in the foregoing case.

The many inconveniences attending the use of a wooden vat—the pouring of the liquor into a copper, for the purpose of giving it the necessary degree of heat, being necessary—have led to the general employment of copper or iron vessels. In England the latter are chiefly used. These are fixed in brickwork, which extends half way up their surface, whilst a stove is so constructed at this elevation, that the flame shall play around their upper part. By this means the vat is heated, and kept at a proper temperature, without the liquor being removed.

The potassa vats are usually formed of conical-shaped coppers, surrounded by a suitable furnace. These may be constructed with less depth, inasmuch as there is less precipitation induced in the liquor. By using steam for heating the vats, the employment of copper vessels might be dispensed with, and so a return to those of wood adopted.

The vats employed for dyeing wool are known under the names of the pastel vat, the woad vat, the potassa vat, the tartar lie vat, and the German vat.

The methods of dyeing by woad or pastel are given by Dumas as follows:—

Pastel Vat.—The first care of the dyer, in preparing the vat, should be, to furnish the bath with matters capable of combining with the oxygen, whether directly or indirectly, and of giving hydrogen to the indigo. These advantages are found in the pastel and woad. The dyer must, however, be careful to employ those substances only which are incapable of imparting to the bath a hue which might prove injurious to the indigo. Madder is used along with the woad; and as this substance furnishes a violet tint when brought into contact with an alkali—hence, by the addition of indigo, it yields a still deeper shade.

The pastel vat, when prepared on a large scale, ordinarily contains from eighteen to twenty-two pounds of indigo. Eleven pounds of madder might suffice for this proportion; but the large quantity of water which one has to charge with oxidizable matters, must be taken into consideration. Even twenty pounds to a vat of this size have been employed, invariably with the best results. Bran is apt to excite the lactic fermentation, and should, therefore, not be employed in too large a quantity; seven to nine pounds will be found amply sufficient.

The weld is rich in oxidizable principles; it burns, sours, and passes into the putrid fermentation with facility. Some dyers use it very freely; but in this bath, an equal quantity of it to that of the bran is commonly employed. Sometimes weld is not added at all.

In most dye-houses the pastel is pounded before introducing it into the vat. Some practical men, however, maintain that this operation is injurious, and interferes with its durability, and such an opinion deserves attention. The effect of the dye-stuff, when reduced to coarse powder, is more uniform; but this state of division must render its alterations more rapid. When the bath has undergone the necessary ebullition, the pastel should be placed in the vat, the liquor decanted, and, at the same time, seven or eight pounds of lime are added, so as to form an alkaline lie capable of holding the indigo in solution. The whole having been well stirred, it should be allowed to repose for four hours, so that the little pellets may have time to become thoroughly soaked, and thus be prepared for fermentation. Some thick coverings are to be spread over the vessel, so as to preserve the menstruum from contact with the atmosphere. After this lapse of time, it is to be again agitated. The bath at this moment presents no decided character; it has the peculiar odor of the vegetals which are held in suspension and solution, and it has a yellowish-brown hue.

Ordinarily, at the end of twenty-four hours, but sometimes after fifteen or sixteen, the fermentative process is well marked. The odor becomes ammoniacal, while, at the same time, the peculiar smell of the pastel is easily perceived. The bath, hitherto of a brown color, now assumes a decidedly yellowish-red tint. A blue froth, which results from the newly-liberated indigoferous matter of the plant, floats on the liquor as a thick scum, being composed of closely agglomerated small blue bubbles. A brilliant pellicle covers the bath; and beneath, blue, or almost black veins may be distinguished, owing to the indigo of the pastel having an ascendant tendency. If the menstruum be now agitated, the small quantity of indigo which is formed floats on the surface of the bath. On exposing a few drops of this mixture to the air, the golden-yellow hue quickly disappears, and is replaced by the blue tint of the indigo. This phenomenon is due to the absorption of the oxygen of the air by the indigo-white of the pastel. Wool might be dyed even at this juncture, without any further addition of indigo; but colors furnished at this period are devoid of brilliancy and vivacity of tone, while the bath becomes quickly exhausted.

The signs above described announce, in a most indubitable manner, that fermentation is established, and that the vat has now the power of supplying to the indigo the hydrogen which is required to render it soluble—that contained in the pastel having been already taken up—and this, consequently, is the proper moment for adding the pulverised indigo.

It was stated above, that the liquor of the vat should be previously charged with a certain quantity of lime; ammonia generated by the pastel is also found in it, but a portion of these alkalies becomes saturated by the carbonic acid gas along with the acid principles of the madder and of the weld, as also by the lactic acid produced by the bran during fermentation. The ordinary guide of the dyer is the odor, which, according to circumstances, becomes more or less ammoniacal. The vat is said to be either *soft* or *harsh;* if the former is the case, it is requisite to add a little more lime. The fresh vat is always soft; it exhales a feeble ammoniacal odor, accompanied with the peculiar smell of the pastel, and lime is therefore introduced along with the indigo—from five to six pounds are usually employed—and after having stirred the vat, it is to be carefully covered. The indigo, being incapable of solution except by its combination with hydrogen, gives no sign of being dissolved until it has remained a certain time in the bath. It may be remarked, that the hard indigoes, as those of Java, require more than six hours for their solution. The vat should be again examined three hours after adding the indigo. The odor is generally, by this time, weakened; a further quantity of lime is again added, sometimes less, but mostly about equal in amount to the first portion; it is then to be re-covered, and again set aside for three hours.

After this lapse of time, the bath will be found covered with an abundant froth, and a very evident pellicle of a cupreous hue; the veins which float upon its surface are larger and more distinct than they were previously; the liquor becomes of a deep yellowish-red tinge. On dipping the rake into the bath, and allowing the liquid to run off at the edge, its color, if viewed against the light, is a well-marked emerald-green, which gradually disappears, in proportion as the indigo absorbs oxygen, and leaves in its place a mere drop, rendered opaque by the blue of the indigo. The odor of the vat at this instant is strongly ammoniacal, but the peculiar scent of the pastel is at the same time discernible. When so obvious a character as this is found in the newly-formed vat, the stuff intended to be dyed may fearlessly be plunged in; but the tints given during the first working are never so brilliant as those subsequently obtained. This is owing to the yellow tinctorial matters of the pastel, which, aided by the heat, become fixed on the wool at the same time as the indigo, and thus communicate to it a greenish tint. This accident is common both with the pastel and the woad vats, though it is less marked in the latter.

When the stuff or cloth has been immersed for about an hour in the vat, it should be withdrawn ; it would, in fact, be useless to leave it there for a longer time, inasmuch as no more of the coloring principle could be taken up. It is, therefore, to be removed from the bath and hung up to dry, when the indigo-white, by attracting oxygen, will become insoluble, and acquire the well-known blue color. If the stuff be now again plunged into the vat, the shade will immediately become deeper, owing to renewed absorption of indigo by the wool. By repeating these operations, very deep shades may be communicated. It must not, however, be imagined that the cloth seizes only on that portion of indigo contained in the liquor required to soak it. Far from such being the case, experience shows that, during its stay in the bath, it appropriates to itself, within certain limits, a gradually increasing quantity of indigo. Here, then, is an action of affinity, or, perhaps, a consequence of porosity on the part of the wool itself.

The army cloth is usually dyed by means of the pastel vat, which gives the most advantageous results. The vats are in this case about eight and a half feet in depth, and five feet in diameter, into which from three hundred and sixty-one to four hundred and five pounds of pastel or of woad are introduced, after previous maceration. The vat is to be filled with boiling water, and twenty-two pounds of madder, seventeen and a half pounds of weld, and thirteen pounds of bran are then added to the bath. The mixture is to be maintained in a state of ebullition for about half an hour; when a few pailfuls of cold water are introduced, taking care, however, not to lower the temperature beyond 130° Fahr.; during the whole of this time a workman, provided with a rake, keeps incessantly stirring the materials of the bath. The vat is then accurately closed by means of a wooden lid, and surrounded by blankets, so as to keep up the heat. It is now put aside for six hours; after this time it is again stirred, by means of a rake, for the space of half an hour; and this operation should be repeated every three hours, until the surface of the bath becomes marked with blue veins; from six to eight pounds of slaked lime are then added.

The color of the vat now borders on a blackish-blue. The indigo is immediately introduced in a quantity proportioned to the shade which we wish to obtain. The pastel in the foregoing mixture may last for several months; but the indigo must be renewed as it becomes exhausted, at the same time adding both bran and madder. In general the following proportions are employed—

11 to 13 pounds of good indigo for 100 pounds of fine wool.

9 to 11 pounds of good indigo for 100 pounds of common wool.

9 to 11 pounds of good indigo for 131 yards of cloth dyed in the piece.

Modified Pastel Vat.—This vat is about seven feet in depth, and six and a half feet in diameter. It is made of copper, and heated by steam. The lid is composed of three segments, each of which is formed of two planks, about an inch thick, and strongly secured together by bolts.

The beating is performed in the usual way, with sticks, before the first dipping, after having moistened the cloth in tepid water. This operation is not subsequently repeated.

This vat is prepared with thirteen pounds of indigo, seventeen and a half pounds of madder, four and a half pounds of bran, nine pounds of lime, and four and a half pounds of potassa. Having filled the vat, it is heated to about 200°, and, as soon as the water is tepid, four hundred and forty-one pounds of pastel are introduced. The liquor becomes of a yellowish-brown color; small bubbles appear upon its surface, ordinarily at the end of four hours if the vat be heated by steam, but not until after eight or twelve hours where heat is applied by the common fire; in the latter case, the mixture should be stirred every three hours. When the liquor displays the signs of fermentation, the above-mentioned ingredients are added, and the vat covered over; it is then to be set aside, stirring it every three hours, or oftener if the fermentative action be very rapid. Each time that it is stirred, from two to four pounds of lime are to be added; if fermentation proceed quickly, even more is used, but in the contrary case less. After about eighteen hours, three pieces of common cloth, measuring twenty to twenty-five ells in each length, are plunged into the vat; when they have received six or seven turns, they are to be taken out again. The object of this is to remove the excess of lime from the bath. The vat is then set aside for three hours, when it is to be stirred, thirteen pounds of indigo, with two pounds of madder added to it, and heat again applied to the mixture.

If the vat contains a superabundance of lime, it will be unnecessary to add more; otherwise a further quantity is thrown in. During the night it should be covered with a cloth, and a workman left to watch it. It is usually stirred once before the morning; but if it be deficient in lime, it will require this manipulation to be more frequently repeated, and also fresh lime added to it. On the following day, the stirring should be continued every three hours, and so on for the next thirty hours, taking care to heat the vat from time to time. On the morning of the fourth day, the dyeing may be commenced.

The temperature should be maintained at a pretty uniform point; if it be too hot, the blue takes a red reflection, by reason of the madder contained in the liquid. A vat thus prepared will last three months; it may even be worked for double that period, but after the third month it appears to lose some of its indigo.

The power of the vat is maintained by introducing every night two and a quarter pounds of madder. A little indigo is also added twice or three times a week. These additions are made in the evening. After the former, the vat is left at rest for forty-two hours ; with the latter, only for twenty-four, at the same time observing the precautions already indicated. At the end of three months, or sooner, when it is desirable to stop the working of the vat, the indigo is exhausted by continuing to charge it every night, for the space of a month, with madder, and dipping into it white cloths, or more particularly woollen tissues, which become more or less loaded with the indigo. This plan must be prosecuted until these matters take up no further color. The dippings are to be performed twice a day at first, but towards the termination only once. Many dyers make use of this bath for preparing a new vat; but it is better to throw this away, and make it up afresh with common water.

Woad Vat.—These vats are extensively employed at Louviers, and in the manufactories of the North of France. The bath is prepared in the same manner as for the pastel vat. The finely-cut root is introduced into the copper along with two pounds of pulverized indigo, nine pounds of madder, and fifteen and a half pounds of slaked lime. The liquor is, after the necessary ebullition, poured upon the woad. This substance contains but a very small quantity of coloring principle; and some indigo must, therefore, be added when preparing the vat, so as to indicate the precise instant when the mixture arrives at the point of fermentation so requisite for imparting hydrogen to the tinctorial matter, and for rendering it soluble. A large quantity of lime must also be employed, since the woad contains no ammonia resulting from previous decomposition, such as is found to be the case with the pastel of the South. When the vat is in a suitable state of fermentation, a rusty color becomes manifest, in addition to the signs already described in speaking of the pastel vat; besides the ammoniacal odor, the bath always retains the peculiar smell of the woad. The pounded indigo is now added, and the operator proceeds in the manner already detailed, to reduce it to a state of solution fit for dyeing.

The vats prepared by means of pastel have greater durability than those made with the woad; but it is thought that the colors given by the latter are more brilliant than those obtained from the former dye.

Indian Vat.—These vats are more simple and of more ready construction than the pastel or woad vats. A quantity of madder and of bran, proportioned to the weight of indigo which it is wished to employ, is boiled in water. After two hours' ebullition, some tartar-lies are added, which are also to be boiled for an hour and a half or two hours, so as to charge the bath with whatever soluble matter they may contain; after this ebullition the bath should be allowed to cool, and the indigo which has been previously ground is then to be introduced. Supposing that twenty-one pounds of indigo are employed, the following would be the proportions used in preparing this vat:—forty-one pounds of tartar-lies, thirteen pounds of madder, and five pounds of bran. These vats are usually mounted in coppers of a conical shape; a small fire should be kept up around them, so as to maintain a moderate and uniform heat. The indigo will usually be found dissolved at the end of twenty-four hours, often even after twelve or fifteen hours. The liquor has a reddish color in the new vats, and a green tint in those which are in a working state. The frothy surface, as well as the brilliant-colored pellicle, become manifested in this as in all other preparations of a like kind.

This species of vat has to be renewed much more frequently than the woad and pastel vats, from the indigo being more difficult to dissolve after a certain lapse of time. A moderate heat should be maintained in all these vats.

Potassa Vat.—This species of vat is extensively employed at Elbeuf for the dyeing of wool in the flock. It presents, in all respects, a perfect analogy with the Indian vat; in fact, the action of the tartar-lie, in the latter preparation, depends entirely on the carbonate of potassa which it contains. The ingredients used in the preparation of the potassa vat are—bran, madder, and the carbonate of potassa of commerce.

The deep shades are obtained in this species of vat with greater celerity than in all others, a fact which undoubtedly depends on the greater power which potassa has of dissolving indigo than is possessed by lime. Experience proves that the potassa vat has the advantage in point of celerity of nearly a third; but this is balanced by the inconvenience resulting from the darker shade, which must be attributed to the large quantity of coloring matter of the madder dissolved by the alkaline lie, and which becomes fixed on the stuff with the indigo.

To render this vat in its most favorable state, the indigo should be made to undergo a commencement of hydrogenation, before turning it into the mixture; for this purpose, a bath analogous to that in the vat is prepared in a small copper, to which the pounded indigo is added. This bath is maintained for twenty-four hours at a moderate heat, taking care to stir it from time to time. The indigo assumes a yellowish color, becomes dissolved, and in this state is turned into the vat: many delays and losses are thus avoided in its preparation; and, indeed, it would be desirable if a similar plan were adopted with all these compounds.

German Vat.—This vat is of nearly similar dimensions to that used for the woad, being three times the size of the potassa vat. Its diameter is about six and a half feet, and its depth eight and a half feet. Having filled the copper with water, it is to be heated to 200° Fahr.; twenty pailfuls bran, twenty-two pounds of carbonate of soda, eleven pounds of indigo, and five and a half pounds of lime, thoroughly slaked, in powder are then added. The mixture is to be well stirred, and set aside for two hours; the workman should continually watch the progress of the fermentation, moderating it more or less by means of lime or carbonate of soda, so as to render the vat in a working state at the end of twelve, fifteen, or, at the most, eighteen hours. The odor is the only criterion by which the workman is enabled to judge of the good state of the vat; he must, therefore, possess considerable tact and experience.

In the process of dipping, eighty-four, one hundred and six, or even one hundred and thirty pounds of wool are introduced in a net bag, similar to that used in the woad vat, taking care that the bag is not allowed to rest against the sides of the copper. When the wool has sufficiently imbibed the color, the bag containing it is removed, and allowed to drain for a short time over the vessel. In this way two or three quantities are operated upon in succession; the vat is then removed, and set aside for two hours; one must be careful, from time to time, to replace the indigo absorbed by the wool, as also to add fresh quantities of bran, lime, and crystallized carbonate of soda, so as constantly to maintain the fermentation at a suitable point.

The German vat differs, then, from the potassa vat by the fact, that the potassa is replaced by crystallized carbonate of soda and caustic lime, which latter substance also gives to the carbonate of soda a caustic character. It presents a remarkable saving as compared to the potassa vat; hence the frequency of its employment; but it requires great care, and is more difficult to manage. It also offers considerable economy of labor: one man is amply sufficient for each vat.

Management of the Vats.—A good condition of the vat is recognised by the following characters:—The tint of the bath is of a fine golden yellow, and its surface is covered with a bluish froth and a copper-colored pellicle. On dipping the rake into the bath, there escapes bubbles of air, which should burst very slowly; when they vanish quickly, it becomes an indication that more lime must be added. The paste which is found at the bottom of the vat, green at the moment of its being drawn up, should become brown in the air; if, however, it remain green, this is a further sign that more lime is required. Lastly, the vat should exhale the odor of indigo. The operator usually completes the assurance of the vat being in a good state by plunging into it, after two hours' respite, a skein of wool, which, on being withdrawn after the lapse of half an hour, should present a green color, but change directly to blue. The materials of the vat are then once more mixed, and two hours after it may be considered ready for dyeing.

These vats, like those already described, are provided with a large wooden ring, the interior of which is armed with a kind of network, for the purpose of preventing the objects which are intended to be dyed coming in contact with the materials at the bottom of the vat; the precaution is taken, moreover, of enclosing the wool or cloth in bags. These tissues, when plunged into the bath, should remain there for a longer or shorter time, according to the shade which it is wished to obtain: one dipping, however, will never suffice for this object; usually the stuff is allowed to remain for half an hour only; it is then to be taken from the bath, wrung, and exposed to the air. This operation is repeated until the desired shade is procured; three hours are ordinarily allowed to elapse between each dipping. The heat of the vat should never be allowed to fall below 130° Fahrenheit. After each operation the bath must be well stirred, and fresh lime added; generally speaking, a pound a day will suffice; the indigo is re-established about every second day. When once this vat is well mounted, and one is careful to examine its working, from two to four batches a day may be dyed with it.

When the stuffs have acquired the desired shade, they are first to be washed in common water, and then in a very weak solution of hydrochloric acid—about one part in a thousand; after this they are again rinsed in pure water.

The Indian vat is much more easily managed than the pastel vat; it presents less danger of failure from the fact that it is quickly exhausted, and also from the fermentative process, which is so difficult to govern in the pastel vat, here not having time to change in character. It is prepared by first introducing an equal quantity of madder and of bran, and a triple quantity of potassa; this is to be gradually heated until it reaches a temperature of 167° Fahrenheit, and the indigo is then added, thoroughly agitating the matters for half an hour. The vat is maintained at a temperature of 86° to 100° Fahrenheit, by keeping it closely covered, and at the same time the mixture is to be stirred occasionally at intervals of twelve hours. It should by this time present a beautiful green shade, the liquor being surmounted by a copper-colored pellicle and a purplish froth. The dyeing may now be commenced, following the same course as with the pastel vat; but the stirrings being here repeated much more frequently than with the other mixture, a larger quantity of wool can be dyed within a given time. When the vat ceases to give a brilliant blue, it must altogether be renewed; if it be merely weakened, a small quantity of freshly-prepared liquor, containing a few pounds of potassa, and a little less bran and madder, is added to it. In giving the dark and the clear sky-blues, one must be careful to employ a quantity of indigo proportioned to the color which it is desirable to obtain, or, better still, the previously exhausted vat may be used for the dark blue.

When exposed to the influence of the putrid fermentation, indigo is decomposed and loses its color. If rendered soluble, it obeys the impulse communicated to the nitrogenized matters with which it is brought into contact, although, if macerated in pure water at the ordinary temperature, it is itself decomposed with great difficulty.

The pastel and the woad are very prone to the putrid fermentation, by reason of the large quantity of nitrogenous matters which they contain, as do all the cruciferæ; they require, therefore, considerable care in their employment.

When a vat is mounted, if the fermentation be allowed to continue unchecked, after the appearance of the blue froth and the other signs already indicated, the liquor will acquire a yellow color similar to that of beer; the froth will become white; it will give out a stale smell, and lose its ammoniacal odor; after a few days it will turn whitish, and exhale a smell at first similar to that of putrified animal substances; then it will acquire the odor of rotten eggs, and set free sulphide of hydrogen. The lime in the pastel and the woad vats, and the tartar-lie and potassa in the other mixtures, are used for the purpose of preventing these accidents.

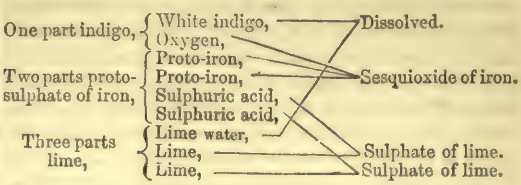
Besides the oxidized compound, which is formed by the combination of oxygen with the extractive matters of the plants held in digestion, there is a production of carbonic acid which saturates the alkaline lie, and forms a carbonate of lime in the pastel vat. This is found attached to the sides of the vat in such quantity, that the inside of these vessels becomes encrusted with it to a considerable depth. It is this product which dyers call the tartar of the vat; it effervesces with acids, and gives on analysis carbonic acid, lime, and a few particles of indigo. In the potassa vat, the solubility of the carbonated alkali prevents its deposition; but it is very probable that there is here a formation of some carbonated products, perhaps in part formed at the expense of the carbonic acid of the air.

The soluble extractive principle being the only matter which remains in solution in the bath with the indigo, the lime, *et cetera*, deposits are formed, which, varying both in their volume, and in the greater or less facility with which they are precipitated during the various periods of fermentation, lead to a more or less considerable waste of time. If a piece of woollen tissue be plunged into a vat which has been recently stirred, it will acquire a dark color, and will be found covered with brown stains, which are with difficulty removed. When the woad or pastel vat has been stirred, it need be left two or three hours only before plunging in the stuff, at least during the early months of its working, inasmuch as the pastel, being but slightly divided and attenuated, is readily precipitated; but when, by reason of its extreme division, in consequence of repeated operations, it is thrown down with less facility, the dipping should not be performed oftener than three times in the day.

The Indian vat requires less time than the others; it may even be dyed with, an hour after stirring the mixture. The potassa, being soluble, forms no precipitate; while the ligneous fibre of the madder and the pellicles of the bran become deposited with great facility. One can also dip with these vats much oftener than with those made by pastel or woad.

Cotton Vat.—The common blue vat for the dyeing of cotton differs from the preceding, both in preparation and materials; the only dyeing agent in it is indigo, and advantage is taken of a beautiful reaction of the ingredients to effect the purposes required. It has been stated—pages 592 and 593—that indigo is insoluble in water, and in most other menstrua, except strong sulphuric acid; but, when deoxidized, the blue indigo is converted into white indigo, in which state it is soluble in alkaline substances; but it becomes again blue indigo by absorbing oxygen, which it does from the air by a short exposure. Advantage is taken of these properties in making up the blue vat for cotton, and in the dyeing of that fabric. The indigo is first ground in water to an impalpable paste, of the consistence of cream. A quantity of this paste is put into a vessel of water, and there is added a quantity of protosulphate of iron and slaked lime, the latter in excess. The whole is well mixed by the rake, when the following reaction takes place:—

First, a part of the lime combines with the sulphuric acid of the sulphate of iron, liberating protoxide of iron, which having a strong attraction for oxygen, supplies itself from the indigo, reducing that body to the state of deoxidized indigo; in this condition, as already stated, it is soluble in alkaline waters, so that the lime, having been added in excess and in a state of solution, dissolves the white indigo, which forms the dyeing solution. The reactions may be stated thus:—



The proportions here given are equivalents. When cotton is dipped into this solution of white indigo, the fibres become filled with it. When lifted out and exposed to the air, the white indigo imbibes oxygen, and becomes converted into blue indigo within the fibre, and constitutes the dye—a beautiful example of chemistry applied to art.

The vats used for dyeing cotton cloth are similar to those described in the preceding pages for woollen and silk; only no heat is required for the cotton blue vat, and it is therefore sunk in the ground to a depth convenient for the operators to work at. This size of vat is also used by some for dyeing yarn, but more generally wine pipes or other large casks are employed for this purpose. These are sometimes sunk into the ground about half their depth, and in some cases they stand on the floor. Five of these constitute a set, and are worked together and kept of the same strength. The yarn being wrought in quantities of one hundred pounds, twenty pounds are passed through each vat. These vats are made up as follows:—Each is filled about three-fourths with cold water, and there is then added eight pounds indigo, sixteen pounds sulphate of iron—copperas—and twenty-four pounds newly-slaked lime. The whole is well stirred with the rake for half an hour, and this is repeated every one and a half hour for the first day. The time to stop this agitation is known by the solution becoming of a rich oak yellow, having large blue veins running through it, and a fine indigo froth on the surface. When these signs are all favorable, the vat is allowed to stand for several hours till all the solid matters settle, when it is ready for use. The reason for employing such deep vessels for vats is to allow room for the collection of the precipitate formed by the sulphate of lime and sesquioxide of iron, which, were they to touch the goods, would deteriorate the color. The mode of dyeing by this vat consists in simply immersing the goods, and working them in the liquor for fifteen minutes, taking out and wringing or pressing, and then exposing to the air. If the tinge is not sufficiently deep by one immersion or dip, this operation is repeated, but generally in a different vat, and so on until the required depth is obtained. The practice is to begin the dye in the weakest and oldest vats, and finish in the newest and strongest, which gives the finest bloom as a finish. All the liquor pressed or wrung out from the goods is put back into the respective vats, and when the operations are finished, the vat is raked and allowed to stand till next day. The yarn is well washed in cold water, and then dried. In some cases it is passed through a tub of water acidulated with vitriol till it tastes acid, and then washed, which adds a little brilliancy to the color when the shade is very deep, and tends to remove some of the iron which may have been fixed upon the fibre.

The quantity of liquid in one of these vats may amount to one hundred gallons, so that, by keeping the proportions stated, any quantity of dyeing solution may be made up. Sometimes, from defects in the materials, such as impurities in the indigo, lime, or copperas, or from other causes, the exact appearances stated may not come up satisfactorily, but a very little practice will enable the operator to vary the process, or add the proper ingredient, so as to produce a good vat. This is a matter, indeed, depending more on experience than on any instructions that can be given. If the indigo is of inferior quality, a greater quantity will have to be used. If the sulphate of iron is new and watery, not only more of that substance, but the addition of lime will be necessary; and if the lime is not newly slaked, it may not be found very effective, as lime that has stood for some time absorbs carbonic acid, and is thus deteriorated for the vat.

MINERAL DYES AND MORDANTS—ALUM.—The history of this article and the various processes for its manufacture have been already given.—See ALUM. Under this head it is stated that the earthy base, alumina, had a strong attraction for organic coloring matters, and hence was used for fixing such upon fabrics; but in order to have the alumina fixed within the fibres of the stuff to be dyed, it must previously be obtained in solution, and this can only be effected by converting the earthy base into a salt; hence the dye produced may be, and generally is, not the pure tinctorial matter adhering to the alumina, but in the state in which it is changed and fixed by the salt, the acid element of which acts an important part in altering the tint of the color. Thus pure alumina put into a decoction of logwood will become deeply colored, but the shade of the hue will be different from that obtained by putting into a similar decoction a solution of alum or acetate of alumina. Even the tints obtained by these last two mentioned substances will differ from each other. This is a circumstance which the dyer must ever bear in view, in regulating his tints either by mordants or alterants; and it is this chemical affinity of the color with the salt of the base that renders it so essential to good results, that the base, whatever it be, should be perfectly pure. Alum—as is stated in the article on that subject—containing the slightest trace of iron, is unsuitable for general use in a dye-house; and so important is this circumstance, that, at the risk of repetition, the method of detecting the presence of iron is appended:—

Dissolve a hundred grains of the alum in distilled water, and then add a few drops of ferricyanide of potassium—*red prussiate*; or first boil the solution, adding previously a few drops of nitric acid. After this, pour in by degrees a little pure carbonate of soda to neutralize the nitric acid, but not to precipitate any alumina; then add further a few drops of a solution of ferrocyanide of potassium—*yellow prussiate*; if any iron be present, a blue color will appear in both cases. Or, to another portion in solution, add a little gallic acid, and, if any iron be present, a slate-colored precipitate will appear. It is recommended that all these tests be applied so as to secure a pure article.

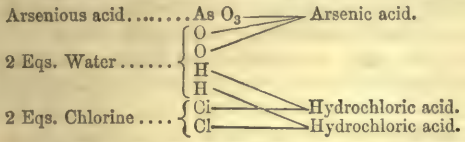
The only method of preparing alum for the dye-house is simply by dissolving it in water. About a pound of alum to the gallon of water makes a good solution. It is not much used as a mordant for cotton, in consequence, doubtless, of the strong attraction which sulphuric acid has for alumina; but it is extensively used in dyeing both silks and woollens, the fibres of which seem to act more powerfully in retaining and fixing the base.

Very nice shades of lavender and lilac may be dyed by making a strong decoction of logwood, and adding to it one pound of alum to the pound of logwood. After standing for a day, the cotton is wrought in this solution and wrung out. Light shades are dyed by adding some of this liquor to hot water, working the cotton in it for some time, and then finishing. This preparation is known as the ***alum plumb tub.*** It is principally used for light cotton cloth.

Alumina, dissolved in acetic acid, is extensively used as a mordant for cotton in various processes of dyeing, and is known in the trade as *red liquor*. The processes for its preparation, and the different results obtained, have been already described under *Acetate of Alumina*—see page 37—to which the special attention of the dyer is called. The modes of using it will be referred to under the particular processes in which its use is required.

ARSENIC.—This metal and its oxides have been already described.—See page 213. Except as a test, it is not very extensively employed in the dye-house, and fortunately so, on account of its highly poisonous properties. The principal use to which it was formerly applied, was for dyeing what are technically called *arsenic sages*, the coloring principle of which is Scheele's green, dyed by working the cotton through an arsenite of soda or potassa and sulphate of copper. With reference to this dye, and the evil consequences resulting from it, NAPIER makes the following remarks:—Common humanity, he says, dictates its complete abandonment as a dye. Nor is the evil so much in the operations of dyeing as in those that succeed: persons who have occasion to work with the yarns after they are dyed, suffer more severely than the dyers. The color being merely a precipitate of the arsenite of copper—a most deadly poison—upon the fibre of the yarn, to which much of it loosely adheres, it is readily disengaged as dust in the dry state, and in the process of winding, especially, much of it is unavoidably inhaled by the unfortunate operative. The result is, as might be expected, that health is seriously impaired, and not unfrequently the consequences are fatal. It is, in fact, consistent with our knowledge, that individuals of this class have never recovered from the effects of winding a quantity of arsenic sage-yarn, for which they were paid *one shilling!* Warpers also are subjected to the same baneful evil, although in a less degree; and even the weaver is not exempt from it. Altogether, indeed, the injury to the community by the use of this dye outweighs a hundredfold that arising from the unrestricted sale of poisons, against which so loud a protest has been raised. One feels fully convinced, moreover, that it is a gratuitous evil, and that dyers would very soon, under the pressure of a little public opinion, find means of avoiding it, and producing the color inocuously, and of a harmless character.—*Manual of Dye.*

Arsenious acid is occasionally used for testing the value of bleaching powder, by the process recommended by GAY-LUSSAC, which depends on the fact of chlorine converting arsenious acid into arsenic acid, the chlorine assuming hydrogen and becoming hydrochloric acid; thus:



A little sulphate of indigo put into the arsenious solution is not decolored, until all the arsenious acid is converted into the arsenic acid. It follows, therefore, that as the equivalent of arsenious acid is 99, while that of chlorine is 35·5, and it requires 2 proportions of chlorine to form arsenic acid, every 99 of the arsenious acid, converted into arsenic acid, will require 71 chlorine. The process may be conducted as follows, taking, for the sake of even numbers, one hundred grains of arsenious acid:—This is dissolved in about four fluid ounces of hydrochloric acid, which generally requires a little heat. The resulting solution is now diluted with six ounces by measure of distilled water, and the whole ought, therefore, to measure exactly ten ounces. It follows that each ounce contains ten grains of arsenious acid. To test bleaching powder, take one hundred grains of the powder, and rub it in a china or glass mortar with a little water; then add as much water as will twice fill an ordinary graduated alkalimeter; allow the coarser grains to settle; then fill the alkalimeter, and, as this is divided into one hundred parts, each part will contain half a grain of bleaching liquor. Take an ounce of the arsenious solution, and add to it a little sulphate of indigo, sufficient to render it a deep blue; then pour into this slowly the bleaching liquor from the alkalimeter, until the blue color disappears, stirring constantly during the operation; mark the number of graduations required to effect this change; and as every 10 grains of the arsenious acid was equal to 7·2 grains of chlorine, so the quantity of bleaching liquor taken to decolor the indigo will contain that amount of chlorine. Suppose, for example, it has required forty-eight graduations of the bleaching liquor to effect the change; this will be equal to 24 grains of bleaching powder, so that 24 grains of the powder will contain 7·2 of chlorine; and if 24 contain 7·2, 100 will contain 30. The powder has, therefore, 30 per cent. chlorine. These operations should be repeated three times upon each sample, and the mean of the three results taken. By a little experience, the whole process is found so simple that a few minutes will suffice to test a sample of bleaching powder. The arsenic solution is best newly made, and is found to lose its quality as a test by standing. This use of arsenic in the dye-house is not deleterious.

CHROMIUM.—This metal was first discovered by VAUQUELIN in 1797. It derives its name from its compounds being all of a brilliant color, but as a metal it resembles cast-iron in appearance. Hitherto, however, it has only been obtained in the state of a powder. It is very difficult to fuse, and is not subject to oxidation when exposed to the air. It resists the direct action of the common acids—sulphuric, hydrochloric, and nitric. It is found native in considerable quantities in combination with lead and iron. The latter combination, termed chrome iron ore, is its principal source, and is found in America, in different parts of the continent of Europe, and in Scotland. The general composition of the ore is one portion of oxide of iron, $Fe\,O$, and one of sesquioxide of chromium, $Cr_2\,O_3$.

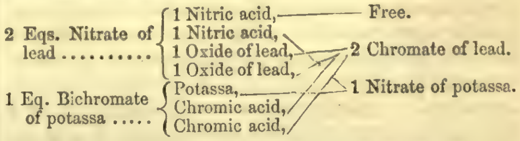
It is capable of combining with two proportions of oxygen, forming—

Sesquioxide,....................	$Cr_2\,O_3$
Chromic acid,..................	$Cr\,O_3$

The oxide is a beautiful green-coloured compound, and is generally obtained from the decomposition of the acid by processes about to be described.

The acid is a brilliant scarlet-red colored compound, and is prepared directly from the chrome ore by crushing the ore very fine, mixing it with a quantity of dried nitrate and carbonate of potassa, and then subjecting the whole to a strong heat in a reverberatory furnace. In this case, the nitrate of potassa is decomposed, supplying oxygen to the chrome oxide, which is thus converted into chromic acid; and this combines with the alkali, forming chromate of potassa, which is afterwards dissolved out by water. This chromate is then converted into the bichromate by the addition of acetic acid, which takes up half of the potassa. The bichromate is next crystallized from its solution, and constitutes the beautiful red-colored salt so extensively used in dyeing, and known in the trade as *chrome.*

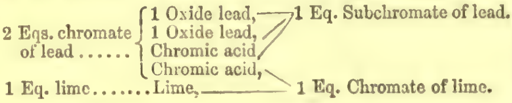
Particulars of the preparation of these salts and oxides, with the later improvements introduced, will appear under the article POTASSA and its Salts. Reference will here be made only to the uses and applications of the bichromate in dyeing. The introduction of this salt into the dye-house effected a complete revolution in certain departments of the art, and it still continues to make inroads upon old processes by new and more extensive applications. Its first use was the production of yellow with the salts of lead. By passing the goods through a solution of acetate or nitrate of lead, and then from that through a bath of bichromate of potassa, a beautiful yellow is obtained, the following reaction taking place between the salts, supposing nitrate of lead has been used:—



It will thus be seen, that when formerly the goods were passed through lead, and then into chrome, some free nitric acid was accumulated in the chrome solution. The same kind of reaction took place with acetate of lead, and this not only induced a strong tendency to change the shade of color, but was hurtful to the fibre, while, at the same time, the process was not economical. These circumstances produced a variety of improvements, which consisted in first converting the lead salt into a subsalt, where two proportions of lead were in combination with one of acid, which met one of the difficulties.

In the dyeing of green, where the cotton was first dyed by the blue vat, given at page 641, and then dyed yellow, as first described, the free acid had a very prejudicial effect upon the indigo; hence it was one of the most difficult dyes to produce of an equal tint. The subsalt of lead did away with this difficulty to a certain extent; but the solution of lead upon the fibre, mixing with the chrome, caused a great precipitation of chromate of lead, producing a rusty color and a loss of material; and, consequently, different solutions of lead were used, and also different matters put into the solution of chrome, which, after these remarks, the reader will be able to appreciate by the processes appended to this article for dyeing yellows, *et cetera*.

Shortly after the introduction of the chrome yellow dye, the dyeing of orange by the same salts came into practice, and was effected as follows:—A strong deep yellow was dyed upon the cotton; after which it was passed through lime-water brought nearly to the boiling point. This produced the following reactions, bearing in remembrance that the yellow dye upon the cotton is the chromate of lead:—



This subchromate of lead possesses a rich orange hue.

The different improvements effected in the dyeing of yellow have been adopted for orange. The object aimed at, with a view to the effective dyeing of this color, is to obtain a large quantity of chromate of lead fixed upon the goods, so as afterwards to produce a rich orange. The formation of subsalts of lead, by boiling the acetate of lead with litharge, has consequently been largely practised for the dyeing of this color.

Bichromate of potassa is also extensively used, along with catechu, for dyeing browns, fawns, drabs, and a great variety of other shades upon cotton. It has of late been much employed in dyeing woollens several shades of browns, blacks, drabs, and slates. With this fabric it acts the part of a mordant, probably by the chromic acid being reduced to the state of sesquioxide of chromium. Some dyers reduce the chromic acid into the state of chromic oxide, previous to using. The following method has been recommended for effecting this reduction:—Dissolve nine pounds of bichromate of potassa in five gallons of boiling water; then put ten pounds of arsenious acid into a boiler containing about twenty-five gallons of water; boil for a quarter of an hour, and allow the liquor to settle; decant the clear portion into a large vessel while the liquor is still hot, and then add to this clear solution the solution of bichromate of potassa, stirring all the time; allow the whole to stand till perfectly cold. It is now put through a filter, upon which is collected the oxide of chrome as a beautiful green-colored precipitate. This oxide is soluble in hydrochloric acid, and may be used, as the dyer finds it convenient, either as a mordant or otherwise. The method of dissolving this oxide in hydrochloric acid, is to dilute the acid with water until it no longer gives off fumes; it is then heated, and when hot, as much of the oxide of chromium is added as the acid will dissolve; the whole is then left to settle, and the clear portion is decanted. Any free acid which may still remain is neutralized by adding gradually a solution of carbonate of soda, until the oxide of chromium begins to be precipitated. The solution thus prepared has a dark-green color. This oxide is not extensively used for cotton, although some beautiful light drabs can be produced by a mixture of this oxide solution with carbonated alkalies; and a variety of shades, varying from blue-black to grey, may be obtained by working cotton in the above-neutralized solution of chromic oxide, and then adding a decoction of logwood. The strength of the solution and logwood must be regulated to suit the depth of color and the particular tint required. The appended recipes will serve to illustrate the use and value of chrome as a dyeing agent, premising that the quantities given are for dyeing ten pounds weight of cotton. Of course the operator may either enlarge or reduce the proportions, according to the quantity of goods to be dyed:—

Light Straw.—To a tub of cold water add four ounces of acetate of lead, previously dissolved; work the goods through this for fifteen minutes, and wring out; into another tub of water add two ounces bichromate of potassa; work the goods through this ten minutes, wring out, and pass again through the lead solution for ten minutes; wash, and dry.

Lemon Color.—Into a tub of cold water put one pound of acetate of lead, previously dissolved; work the goods in this for fifteen minutes, and wring out; into another tub of cold water put six ounces bichromate of potassa in solution; work the goods for fifteen minutes through this, and wring out; then put back, and work ten minutes in the plumbous solution; wring out, wash, and dry.

Deep Yellow.—To a tub of cold water add one pound acetate of lead, and one pound nitrate of lead in solution; work the goods in this for half an hour, and wring out; then in a tub of warm water add twelve ounces chrome, and work the goods from the lead through this for fifteen minutes; expose to the air for half an hour, then pass again through the lead and chrome, working the same time in each as before, and allow an hour's exposure out of the chrome the second time; then pass through the lead; wring out, wash, and dry. If not deep enough, a third dip may be given, observing the same rules.

Deep Amber Yellow.—Put into a tub of water one pound acetate of lead, and to this add gradually caustic potassa or soda, until the precipitate formed be redissolved, taking care not to add more alkali than is required for this solution. The goods are then wrought through this for half an hour; wring out, and then add eight ounces chrome in another tub of water, and work the goods in this for fifteen minutes; wring out, wash, and dry. Two or three ounces of sulphate of zinc may be added to the chrome solution with good effect. If a red deep amber be required, add to the chrome solution one half pint muriatic acid.

Chrome Green.—Dye a blue by the vat described at page 641; then, on the top of the blue, dye a yellow, by the last recipe. Of course the depth of blue and yellow will regulate the tint of green. So that the proportions named for the yellow may be smaller, and the dips or immersions repeated more or less frequently, as required. The principal difficulty is when a particular depth or shade of green is wanted, to ascertain the exact shade of blue to be given, as blue cannot be added upon the yellow. This is a matter, indeed, which can only be learned by practice; but a very short experience will suffice.

The Editor also annexes a few receipts for dyeing with bichromate of potassa upon woollens, the quantities stated being for five pounds of woollen, either in thread, cloth, or wool. It ought to be premised that the woollen must always be well cleaned before dyeing, and that the dyeing must always be performed at a boiling heat:—

Black.—Work for one hour in a bath with eight ounces bichromate of potassa, six ounces alum, four ounces fustic; lift, and expose to the air for a short time; wash well, and then work for one hour in another bath with four pounds logwood, four ounces barwood, four ounces fustic; lift, and add four ounces copperas in solution; work half an hour in this, and then wash and dry.

Blue-black is first dyed blue by the vat, or by ferrocyanide of potassium, or *yellow prussiate*, as will be afterwards described, and then proceeded with as directed in the above receipt, only using less materials.

Brown.—Work for half an hour in eight ounces of chrome; lift, and expose till cold; then into a new bath work an hour in two pounds fustic, four ounces madder, three ounces cudbear, four ounces tartar, two ounces logwood; lift out, and dry; or it may be washed before drying.

Rich Yellow Brown.—Work for an hour in the following bath: two ounces bichromate of potassa, two ounces argol, two ounces alum; wash from this bath; then work about forty minutes in another bath made up with two pounds fustic, one pound madder, eight ounces peachwood, four ounces logwood; wash out of this, and dry. This gives a very beautiful brown; and a great variety of tints and shades may be made by varying the quantities of the last bath, with the same preparation as the first bath.

Rich Yellow.—Work for half an hour in a bath with three ounces chrome, two ounces alum; lift, and expose till well cooled and drained; then work for another half hour, without previous washing, in another bath with five pounds fustic; wash out, and dry.

Bottle Green.—Work for an hour in a bath with two ounces chrome and four ounces alum; lift out, and expose to the air for some time till the goods are cold; then work for an hour in a second bath with three pounds fustic, one and a half pound logwood; wash out, and dry.

Invisible Green.—Work for an hour in a bath with three ounces chrome, four ounces alum; lift, and expose to the air for some time; then work for an hour in a second bath with two pounds fustic, three and a half pounds logwood; wash out, and dry.

By comparing these two last receipts, it will be seen that the different shades are produced by varying the proportions of the same stuffs, and they will serve as a guide to the amateur.

Olive.—Work for an hour in a bath with four ounces chrome, two ounces alum; lift, and expose for some time to the air; then work for an hour in a bath with three pounds fustic, one and a half pound camwood, one pound logwood; lift out, and dry.

Purple.—Work the goods half an hour in a bath with one ounce chrome, one ounce alum; lift out, and wash in cold water; and then work half an hour in a bath with two pounds logwood, one pound peachwood; lift, and add one ounce of alum in solution; work in this for twenty minutes; wash, and dry.

If a light and redder shade be required, use less logwood and more peachwood; and if a darker shade, more of each.

Rich Green Drab.—To the dye bath add one ounce bichromate of potash, half an ounce alum, half an ounce tartar, and work the goods in this half an hour; lift out, and wash through cold water. Make up a new bath of water, and add four ounces logwood, two ounces fustic, one ounce barwood, or half an ounce peachwood; work the goods again through this second bath half an hour; wash, and dry.

Shades of this can also be varied by using different proportions of stuffs.

Rich Drab.—Dissolve half an ounce of bichromate, and add the required quantity of water; work in this for half an hour; lift the goods, and add one ounce of logwood; work again for half an hour; lift out, wash, and dry.

Different shades of this drab may be made by varying the quantities of the dyestuffs.

These recipes might be greatly multiplied; but those which have been given will serve as a guide for practice, and will sufficiently illustrate the extensive use to which bichromate of potassa has been applied in the dyeing art. These directions are also so simple and easy, that the amateur may put them in practice without the risk of failure; and it may be mentioned, that the quantity of water to be used is not material; this will be regulated according to the size of the vessel, and the number of goods to be dyed; but there should always be enough of water to cover the goods without the necessity of pressing them down. Rules for making up decoctions and other manipulations will be given at the end of this article.

COPPER SALTS.—These have been already treated of under COPPER and ACETIC ACID, and do not require to be further noticed here, except with reference to their use as dyeing agents. In the dye-house they are not very extensively used; they have a peculiar influence in many operations, from their property of yielding oxygen, and thus, for many purposes, they act a very important part, well known to practical men, but not yet easily defined on scientific principles. They are very little used in the dyeing of cotton goods.

Sulphate of copper is used among catechu for destroying the gummy principle in that drug; it is also employed with copperas, for certain tints and shades of black and brown upon cottons and woollens.

Acetate, or subacetate of copper, is, however, the salt most in fashion for an alterant, its acid being not so destructive to vegetal dyes as that of either the sulphate or nitrate. The last-named salt, when used, is generally prepared by the dyer himself, by dissolving a piece of metallic copper in nitric acid, mixed with a little water, adding as much copper as the acid will take up.

Vast quantities of this salt are obtained from the etching of copper rollers, and in many large print-works it is looked upon as a sort of refuse, and sold at a small cost. An ingenious application of this waste salt, and which is well worthy the notice of dyers and others who may have quantities of this waste article, was lately patented by a Glasgow manufacturing chemist, Mr. DUNN. His process consists in adding to the acid salt as much litharge as will combine with any free acid present; and after effecting this saturation, he inserts into the solution sheet-lead, upon which is deposited the copper; the whole solution is by this means converted into nitrate of lead, which is evaporated and crystallized. The precipitated copper is separated from any lead that may remain, and then heated sufficiently to effect oxidation; after which it is digested in sulphuric acid and water, forming the sulphate of copper, which is boiled down and crystallized.

IRON SALTS.—Some of these have earlier received attention—see ACETATE OF IRON; others will be treated of in their proper places; at present the uses of these salts in the dye-house will be explained. An important application of sulphate of iron—copperas—has been already referred to when treating of the common blue vat; but the selection of copperas for this purpose is a highly important consideration. There is a watery-looking pea-green colored crystal very common in the Scotch market, and which is not a good copperas for the blue vat; when tested, it invariably exhibits a deficiency of iron, and a higher proportion of acid than theory allows; and when such copperas is used for a vat, a greater quantity of it is required, and also more lime; the precipitate in the vat takes a much longer time to subside, producing what is technically termed *swimming*, which affects the dye, and is an annoying circumstance to the dyer. The copperas best suited for the blue vat should have a dark rusty-green color, and care should be taken that it contains no impurities, such as copper, zinc, or alumina, as the presence of these matters neutralizes the effects of iron in reducing the indigo, naturally suggesting that the dyer should be acquainted with the means of testing the quality and value of his stuffs. The following are a few simple rules for copperas:—Dissolve one hundred grains of the crystals in four ounces of distilled water in a glass or china vessel, add to the solution one-fourth of an ounce of nitric acid, and bring the whole to ebullition; this converts the iron to the state of sesquioxide. Divide the solution into four equal parts. To one part add an excess of caustic potassa, and boil for ten minutes; pass the whole through a filter, and fill the filter several times with water to wash the precipitate, which may afterwards be thrown away; to the clear solution add sulphuric or hydrochloric acid until it reddens blue litmus paper; then add ammonia till the solution smells of that liquid, and allow it to stand over for half an hour. If a white precipitate appears, either immediately or after standing, then alumina is present, and the copperas should not be employed for the blue vat.

To another part of the original solution add ammonia in excess, and filter, washing the precipitate as before; but this precipitate is not to be thrown away. If copper be present, the solution will have a bluish tint, and the copperas should not be used for the vat; if no blue tint shows itself, and no alumina, dry the filter with the precipitate, and then burn the whole at a red heat for ten minutes, or until the filter is all consumed; sesquioxide of iron remains, and this must be carefully weighed; then, as eighty of this is equal to seventy-two protoxide, so will the weight of the residue obtained be equal to the protoxide originally in the copperas; and the quantity of the solution being a fourth of the one hundred grains, the result is multiplied by four for the per centage. The following is the theoretical composition of copperas:—

	Centesimally represented.
Protoxide of iron,	25·9
Sulphuric acid,	28·8
Water,	45·3
	100·0

So that, if the quantity of protoxide of iron be less than twenty-six per cent., the copperas is inferior; it ought to be nearer to twenty-seven for good old copperas.

To the third portion of the original solution add a solution of chloride of barium, so long as there is any precipitate formed, and allow it to stand for half an hour; then filter, and wash the filter till a little of the water passing through, caught in a clean glass, gives no precipitate with sulphuric acid; when thus washed, the filter with its contents is dried, and then burned in the same way as the iron precipitate; the remainder is weighed, and calculated by this equation:—As 116 sulphate of baryta is equal to 40 sulphuric acid, so is the weight obtained to the sulphuric acid present in the copperas; the result multiplied by 4 gives the per centage, which should not exceed 29 per cent., as given above. If, as is often the case, the result be 30 per cent., there is something wrong.

If these operations are carefully performed, the fourth portion of the liquor will not be required; and if the results of the trials be satisfactory, the dyer may go on to use his copperas without fear, either for the blue vat or any other purpose; and although little impurities may not be of so much consequence in some of the uses to which copperas is applied, as when it is employed for the vat, still the pure article is always the best and most economical.

Copperas is extensively used in the dye-house for a variety of purposes, from the property it possesses of forming black compounds with vegetal astringent substances, such as gallic acid and tannin; and, as already stated under the various vegetal dyes, many of these contain astringent matters. Iron is consequently of universal use, both as a mordant or base, and as an alterant, and, from its sombre effect when used as an alterant, it has got the significant epithet of *saddening*.

In this salt, as with alumina, although the oxide of iron has a powerful attraction for the vegetal matters, still the acid which is in union with the oxide exercises a strong resistance. Thus, copperas having an excess of acid will not give so deep a dye upon cotton with the same quantity of sumach as dry neutral copperas, nor will either give so deep a tint as the same quantity of oxide of iron if held in solution by acetic acid. Hence acetate of iron is a more powerful mordant than copperas. Moreover, the reaction of acetic acid upon the other coloring matters that are often present in the vegetals, renders that salt of iron much more useful than copperas for many purposes—see page 41. The latter, however, is most generally used in the dye-house. It is much cheaper, and can be applied with greater facility. Solutions of copperas are liable to become slightly changed by attracting oxygen, and the metal being converted into the sesqui. Iron does not in that state suit well for dyeing with astringent matters, as the peroxide reacts upon the vegetal, and causes loss.

Upon this reaction, and the effect of iron salts upon tannin and gallic acid generally, Professor CALVERT has made some interesting investigations. The conclusions at which he arrives are these:—1. There can be no doubt that tannic acid is the matter in tanning substances which produces black with iron mordants. 2. That the reason why gallic acid produces no black dye is to be found in the circumstance, that it reduces the peroxide of iron in the mordant, forming a colorless and soluble gallate of protoxide of iron. 3. That gallic acid has the property of dissolving iron, and thus lays claim to the character of a true acid, whilst tannin, not having this action, appears to be in reality a neutral substance. These observations, some of which had been previously pointed out by NAPIER, must be of considerable importance to the dyer, and they agree with experience.

Copperas is also used as a mordant for dyeing blue by ferricyanide of potassium. Thus, ten pounds of cotton may be dyed a good rich blue, by working it for fifteen minutes in a solution of four pounds of copperas, wringing from this, and then working through a solution of four ounces of the ferricyanide; finally, washing in cold water containing an ounce of alum in solution.

Copperas is also used as a dye, by the oxidation of the iron within the fibre, thus:—

Iron Buff or Nankeen.—Take two pounds of sulphate of iron and dissolve them in warm water, and then add the requisite quantity of water for working the goods, work in this for twenty minutes, and wring out, and put them immediately into a separate vessel filled with lime-water, and work in this for fifteen minutes; wring out, and expose to the air for half an hour, when the goods will assume a buff color. If the color is not sufficiently deep, this operation may be repeated, working through the same copperas solution, but using fresh lime-water each time. The goods are then washed through clean warm water, and dried.

Chloride of Iron is another salt seen in the dye-house, and is prepared for use thus:—To four parts of hydrochloric acid add two parts water, and apply a gentle heat, then add iron in pieces or filings, so long as it continues to be dissolved; then pour off the clear liquid into a basin, and evaporate, when greenish-colored crystals of chloride will be obtained; but this salt crystallizes with difficulty, and deliquesces in the air, and should not be exposed. Instead of evaporating and crystallizing, the solution may be put into a bottle and reserved for use.

This salt is used for dyeing silks and woollens of a deep blue, and is preferred for that purpose to copperas.

To dye five pounds of silk a rich deep blue, add to water required to work the silk two pints of chloride of iron, and one pint *double muriate* or chloride of tin—see page 651; work in this half an hour; lift, and work in a solution of eight ounces ferrocyanide. If the color be now the required depth, wash out in water in which two ounces of alum have been dissolved; but if not sufficiently deep, put it again through the iron and ferricyanide solutions, and then wash out.

Five pounds of woollen will be dyed a deep blue by putting into the required quantity of water, one quart of chloride of iron, and one pint of chloride of tin; work in this for half an hour; lift, and work half an hour in a bath with four ounces of the ferricyanide. If the color is required deeper, repeat this through the same stuff, adding two ounces more red prussiate; then wash out in cold water, and dry.

Nitrate of Iron is another salt much used in the dye-house for several purposes. It is prepared by dissolving iron in nitric acid. Take four pounds nitric acid and one part water in a glass or stoneware vessel, and place it in a warm solution, then add clean iron so long as the acid continues to dissolve it with effervescence; take out any remaining iron, and, after settling for an hour, the clear solution is ready for use. One need hardly mention that the fumes given off in this operation are deleterious to health, and injurious to every metal or vegetal with which they come in contact. The chemistry of this salt will be given under the article IRON; but in the meantime it may be remarked, for the guidance of the dyer, that the salt thus prepared should be kept in the dark, as the light, according to NAPIER, has a wonderful effect upon its dyeing quality. If two equal quantities of the iron solution are kept, the one in the dark, and the other exposed to the sun's rays, for several hours, and then both are used for dyeing the same weight of goods prussian blue, that which has been kept in the dark will give a blue much deeper than that which was exposed to light. This salt is not used for the same purposes as copperas with astringent vegetal matters. Its principal use is for dyeing prussian blue, which may be performed as follows, the proportions being for ten pounds of cotton:—

For Sky Blue.—The cotton should be previously bleached, then to a tub of cold water, sufficient to work the goods in easily, add half a pint nitrate of iron, and then work in this for twenty minutes; wring out, and pass through one tub of clean water. Into another tub of cold water add four ounces ferrocyanide of potassium in solution, and about a wine-glassful of sulphuric acid; work the goods in this for fifteen minutes; wring out, and wash through cold water, in which is dissolved one ounce of alum; wring out, and dry.

To dye lighter or darker shades of sky-blue, use less or more of the iron and ferrocyanide; or should the shade be too light after passing through the processes described, by repeating the operations through the same tubs, only adding an ounce more ferrocyanide, the shade will be deepened nearly double.

Napoleon Blue.—The cotton to be bleached before dyeing. Into a tub of cold water add one imperial pint of nitrate of iron, and two gills hydrochloric acid, then add three ounces crystals of tin, or a pint of double muriate; stir well, and immediately enter the goods, and work for thirty minutes; wring out, and put directly into the *prussiate tub*, made up with water, into which is put a solution of twelve ounces ferrocyanide, and one wine-glassful of hydrochloric acid; work in this for fifteen minutes, then wash out in clean water in which is dissolved two ounces alum. If a deeper shade of blue is required than these quantities will give, the goods are washed from the prussiate tub, without alum, in water, and passed again through the iron and ferrocyanide, and then washed out, as above, with alum in last water.

Royal Blue.—This is dyed in the same manner as the above; but the liquors are stronger—using two pints iron, two gills hydrochloric acid, and four ounces tin crystals. The prussiate tub is made up by dissolving in it one pound ferrocyanide of potassium, and adding one wine-glassful of sulphuric acid, and one glassful hydrochloric acid. All the other operations are the same as the preceding. If not sufficiently dark with putting once through, repeat.

For five pounds of silk the following proportions of stuffs are used:—

Sky Blue.—To a sufficient quantity of cold water to work the goods, add half a pint of nitrate of iron; work in this for twenty minutes, then wash out in cold water.

Into another vessel of cold water add three ounces ferrocyanide of potassium in solution, and one ounce, by measure, of strong sulphuric acid; work through this for ten minutes, then wash in cold water, in which an ounce of alum has been dissolved, and finish.

Royal Blue.—Into a vessel with cold water add two pints of nitrate of iron; then take one pint water and half pint hydrochloric acid, and to this add three ounces crystals of tin; when dissolved, add this to the vessel containing the iron, or one pint double muriate of tin; stir well, and enter the goods immediately, and work for half an hour.

Into another tub dissolve eight ounces of the ferrocyanide, and add to it two ounces, by measure, of sulphuric acid; the goods are wrung out of the iron solution, and put directly into the second vessel with the ferrocyanide, working for fifteen minutes; then wash out in cold water, having two ounces of alum dissolved in it, and finish.

Should the shade not be sufficiently deep, instead of washing in the alum water, they may be put back into the iron solution, and again through the ferrocyanide in the same way, and work the same time as first, only adding two ounces of the latter salt before entering the second time into that vessel; then finish as stated.

Deeper shades are obtained by using more iron and tin, or by giving several dips.

Some wash out the iron solution before going into the ferrocyanide in one water, and also wash it out before putting back into the iron; the shade by this will not be so deep with the same stuff, but there is less risk of an unequal color.

Woollens may also be dyed different shades of blue with nitrate of iron, observing the general rule, that the woollen must be wrought at a boiling heat. For five pounds of this material the following processes are used:

Royal Blue.—Work for twenty minutes in a bath with one pound of the ferrocyanide of potassium, and lift; then take half a pint nitrate of iron, and add to it one ounce of the crystals of tin, or one pint chloride of tin; stir well for a few minutes, and then add this mixture to the bath, and work the goods in this for half an hour; wash out, and dry.

It is almost unnecessary to repeat, that different quantities will give various depths of color.

Nankeen or buff colors are dyed directly upon cotton by the nitrate of iron. To a tub of hot water add one pint of nitrate of iron, and work in this for half an hour ten pounds of cotton previously bleached; wash out in water, and dry. No process could be more simple and easy, and this produces a permanent dye.

These few receipts will show the importance of iron as a dyeing agent. Its further use in the dyeing of blacks, slates, *et cetera*, will be given at the close of this article.

Acetate of Lead.—See page 43.

Nitrate of Lead.—This salt, with the several oxides and other salts having the same base, will be treated of under the article LEAD.

Basic salts of the acetate of lead are prepared for dyeing oranges, and several deep shades of yellow, by boiling a solution of acetate, either white or brown, and adding to it a quantity of litharge, which is taken up, forming salts having two, three, and sometimes six proportions of oxide of lead to one of acid. These are found to be more suitable than the simple acetate. The only use of these lead salts in the dye-house is for dyeing yellows, greens, and oranges. They have therefore no application apart from bichromate of potassa, which has been already given.

MANGANESE.—A few years ago, the salts of this metal were introduced as a dyeing agent in the production of browns, depending entirely upon the formation of an oxide of the metal within the fibre of the stuff.

The salts of manganese belong to the protoxide; but when the acid which is in union with the oxide is removed, the protoxide passes into the peroxide, which has a deep brown color approaching to black. So that when cotton was steeped or worked for a time in a solution, say of protosulphate of manganese, and then through a weak solution of an alkali, the acid and alkali combined and were dissolved, while the oxide was left on the cotton. Hence, by exposure to air, it absorbed more oxygen, and passed to a brown; or by passing the cotton through a little bleaching liquor, the oxidation of the manganese was immediately effected, and thus browns and fawns of various shades and depths were dyed, according to the strength of the manganese salt, or the number of times the operation was repeated. The colors produced by this means had a heavy dull appearance, and are now very seldom dyed, having been superseded by catechu, which produces similar colors of a lively rich hue.

PRUSSIAN BLUE.—For the manufacture of red and yellow prussiate—see article POTASSA *and its Salts.* Here the use of these salts in the dye-house for the production of prussian blue will be dwelt upon. Under the head IRON, in this article, it has been stated that the different salts of that metal have a kind of reciprocal action upon these two salts of potassa, and that, with the sesquioxide salts and yellow prussiate, there is produced the same deep blue color as with the protosalts of iron and red prussiate. This kind of action occurs with several metals, and gives the dyer a considerable power of varying his processes and tints. The following table exhibits these reactions:—

	Red prussiate.	Yellow prussiate.
Protosalts of manganese,	Brown,	White, becoming red.
Lead,	No precipitate,	White.
Sesquisalts of iron,	No precipitate,	Deep blue.
Protosalts of iron,	Deep blue,	Bluish-white.
Copper,	Yellow-green,	Brown.
Protosalts of tin,	White,	White.
Persalts of tin,	No precipitate,	Yellow.
Zinc,	Orange-yellow,	White.
Bismuth,	Yellow,	White.
Cadmium,	Yellow,	White.
Cobalt,	Red-brown,	Green.
Nickel,	Yellow-green,	Greenish-white.

These two salts—yellow and red prussiate—are of the utmost value to the dyer. From the above table it will be seen that different colors may be produced by using different metallic salts; as, for example, copper and ferrocyanide of potassium. By working the goods in a solution of sulphate of copper, and then passing them through a solution of yellow prussiate, a rich brown is produced of great permanency, and this method is occasionally practised.

The principal use of these prussiate salts, however, is in dyeing blues by the salts of iron, examples of which have been given under the head IRON, in this article; other instances will be appended towards the conclusion, but, in order to explain the nature of the process by which the color is produced, the yellow prussiate may be defined as a double salt of iron and potassium, combined with cyanogen, namely, one part cyanide of iron and two parts cyanide of potassium.

Thus—

$$2\ (\mathrm{K\ Cy})\ \mathrm{Fe\ Cy\ or\ K_2\ Cfy}.$$

The mere introduction of oxide of iron into a solution of yellow prussiate, will not convert the iron into prussian blue; and therefore, if a piece of calico, having its fibres saturated with oxide of iron, were passed through a solution of pure ferrocyanide of potassium—yellow prussiate—there would be no blue dye obtained, as the potassium would retain the cyanogen, and prevent it combining with the iron. The presence of an acid is requisite to unite with the alkali-metal, thus setting the cyanogen free to combine with the iron. When the goods are dyed by lifting them out of the iron solution, and putting them directly into the solution of yellow prussiate, in that case the acid of the iron seizes the potassium, and a mutual transference ensues. Two equivalents of nitrate or sesquichloride of iron and three equivalents of ferrocyanide of potassium, yield one equivalent of prussian blue and six equivalents of chloride of potassium, as represented by the equation—

$$2\ (\mathrm{Fe_2\ Cl_3}) + 3\ (\mathrm{K_2\ Cfy}) = \mathrm{Fe_4\ Cfy_3} + 6\ \mathrm{K\ Cl}.$$

So far as regards the method of dyeing just described, there is no difficulty; but when the cloth is impregnated with the iron salt, and the acid is removed either by washing or passing through an alkali, as is often done, in that case acid must be added to the prussiate solution to liberate the cyanogen. If care is not taken in practising this process, a certain loss will occur. When the acid is added to the prussiate solution, a great quantity of the cyanogen passes off as hydrocyanic acid, and there is formed a new compound of iron and the liberated cyanogen. This, indeed, is also a species of prussian blue, but the product is far short of what would be obtained if no acid had been added. These observations will guide the intelligent dyer in his mode of proceeding with this agent. The same remarks apply also to red prussiate in its practical application. Colors dyed by the prussiate should be exsiccated in a dry atmosphere; for heat and moisture have a strong action on prussian blue, producing first a reddish tint, which passes into lavender and then into grey, and if the action is continued the tint is completely destroyed. It is easily affected also by the sun's rays, and likewise by washing in distilled or rain water. All alkaline matters destroy it. In the deeper shades of prussian blue, where tin salts are used along with the iron, the color is much more permanent. All kinds of fabrics—cotton, silk, and woollen—admit of being dyed prussian blue.

TARTAR.—*Argol—Cream of Tartar—Bitartrate of Potassa.*—This salt is much used as a mordant for the dyeing of woollen stuffs. It is seldom employed alone, but mostly with alum, sulphate of iron, and chloride of tin. Its use, along with these bodies, is very important, owing, as is generally supposed, to a decomposition taking place, in which the sulphuric acid of the alum and iron, and the chlorine of the tin, unite with the potassa of the tartar, resulting in the formation of a tartrate of alumina, iron, or tin, which combines more easily with the woollen stuff. Upon this action DUMAS has the following:—

Cream of tartar, or bitartrate of potassa, constitutes by itself a feeble mordant, but which is very often used in dyeing light woollen stuffs, to which one may wish to give a delicate but brilliant shade. It is also employed in the dyeing of ordinary woollen goods, but here it is associated with alum, sulphate of iron, chloride of tin, *et cetera*. Its influence, under these circumstances, consists evidently in determining a double decomposition, from which a sulphate of potassa or chloride of potassium is produced, whilst the tartaric acid combines with the alumina, the sesquioxide of iron, or the oxide of tin. Now, it is very probable that the coloring matters remove the alumina, the sesquioxide of iron, or the oxide of tin, more readily from tartaric than from sulphuric acid. Moreover, the presence of free sulphuric acid would certainly prove injurious, as well to the stuff as to the coloring matter, whilst free tartaric acid can exercise no unfavourable action over them.

The operation of subjecting wool to the alum mordant is always effected at the boiling point; the mixture used in this process is a compound of alum and of cream of tartar. One of the objects of this addition is to free the bath of the carbonate of lime which the water generally retains in solution, and which, acting on the alum, would determine its partial decomposition by producing an insoluble subsulphate of alumina and potassa, and this accumulating on the stuff, and becoming unequally fixed upon its surface, would lead to stains or blotches on passing the material through the dye-bath. But, independently of the above effect, which might be produced by any acid, cream of tartar appears to be capable of effecting a further object, by inducing a double decomposition, which transforms the alum into a tartrate of alumina. However this may be, after one or two hours' boiling in the alum-bath, the cloth, which should be constantly agitated so as to cause a more equal application of the mordant, is withdrawn from the copper, and after thoroughly draining, it should be put aside for two or three days, when it is wished to dye it with any full-bodied color. Experience has proved that this repose after the use of the mordant greatly favors the union of the latter with the stuff. In applying the tin mordants, use is also made of cream of tartar. It is, moreover, an indispensable addition where it is desired to fix the salts of iron previously to dyeing in black.

Woollen cloth, on being dipped into a cold aqueous solution of alum, appropriates to itself a part of this salt, but without undergoing any very sensible alteration. MM. THENARD and ROARD have, indeed, proved that cloth, when thus treated by a cold solution of alum, gives up this salt to boiling water, and that, after a few washings performed at the boiling point, it will have parted with the whole of the alum which it had received in the cold bath. When, however, cloth is boiled in a solution of alum, it yields to this liquid a portion of its organic matter, which becomes dissolved; but, at the same time, it absorbs an equal amount of the alum.

It will now merely be necessary to show the action which wool undergoes when brought into contact with alum and cream of tartar at one and the same time. It is very possible that there may be in this case a simultaneous fixation of alum, as well as of the double tartrate of alumina and potassa, and of tartaric acid. The presence of alum in the cloth when taken from the boiling solution is very evident; that of the tartrate of alumina and potassa and of free tartaric acid is only presumable.

Tartar is often adulterated when sold to the dyer. Its adulterations are generally sand, carbonate of lime, alum, and sulphate of potassa. By boiling one hundred grains of the tartar in a solution of carbonate of potassa or borax, the sand, if any be present, will remain as an insoluble residue, and may be weighed.

Take another one hundred grains of the same, finely ground, to which add a little water, and then a little dilute hydrochloric acid; if lime be present, there will be effervescence. After allowing it to stand for half an hour, add ammonia till the solution smells of that alkali; then put the whole upon a filter, and wash; to the clear filtrate add a solution of oxalate of ammonia, which will precipitate the lime; this, when filtered and burned, gives the quantity of carbonate of lime in the sample.

Dissolve another portion in water, with a little hydrochloric acid, and filter; to a part of the filtrate add a few drops of chloride of barium; if a white precipitate is formed, sulphuric acid is present. To the other portion of the filtrate add ammonia; if no precipitate is formed by this, then the adulterant will be sulphate or bisulphate of potassa; but should there be a white gelatinous precipitate by ammonia, alum is present in the tartar. The latter salt is not injurious to the process to which the tartar is applied by the dyer; but it is well that he should know the quality of the stuff before using it. Oxalate of potassa and soda is occasionally used as a substitute for tartar, but is not so effective as a mordant.

TIN.—The oxides of this metal have been long known as a mordant for dyeing, as stated in the course of the historical remarks; and the salts of tin are still among the most useful and extensively used of any substances in the art. The oxides have a strong affinity for vegetal coloring matters, and also a strong tendency to combine with or become insoluble within the fibres of the goods submitted to their action, thus rendering them peculiarly suitable as mordants. Tin combines with oxygen in different proportions, while its oxides combine with acids, and give rise to a series of salts of distinctive qualities, but all more or less useful in dyeing. These oxides have the following composition:—

Protoxide,	$Sn\,O$
Sesquioxide,	$Sn_2\,O_3$
Peroxide,	$Sn\,O_2$

The first and last of these form with acids permanent salts, known by the affixes *pro* and *per*, or distinguished as stannous and stannic salts. The sesquioxide salts are generally found and used in combination with other salts, such as those of iron, forming also important compounds for dyeing purposes.

Protochloride of Tin—commonly called salts of tin—is obtained in the market in the form of white prismatic crystals, which, according to Dr. PENNY, contain two equivalents of water, and are therefore composed of—

		Centesimally.
1 Eq. Tin,	59·0	52
1 Eq. Chlorine,	35·5	32
2 Eqs. Water,	18·0	16
	112·5	100

Other chemists, however, have assigned three atoms of water, in which case the composition will be—

		Centesimally.
1 Eq. Tin,	59·0	48·1
1 Eq. Chlorine,	35·5	29·5
3 Eqs. Water,	27·0	22·4
	120·5	100·0

The quantity of tin found in the salts of commerce generally agrees better with the latter analysis than the former. When these salts are put into water they produce a milky-colored solution, owing to the formation of an oxychloride of tin, which is insoluble. A little hydrochloric acid put into the water prevents this to a large extent.

Besides these crystals of tin, there are also obtained in the market solutions of protochloride of tin, under the name of *single* and *double muriate*. The former is a solution of tin in hydrochloric acid, with excess of acid, and the whole diluted with water. The quantity of tin in good single muriate is 12 per cent.

Double muriate is the same salt as the single, but more concentrated, having in it about 25 per cent. of tin. Both these salts vary very much in quality, and should always be subjected to a testing process. That recommended by Dr. PENNY is very easy and simple, and also very correct in its results; here the Editor appends it at length:—

The principal object of the present communication, says the author, is to make known a ready process for estimating the value of protochloride of tin.

This compound, it is well known, is extensively employed by dyers and printers, under the names of crystals, or salt of tin, and single and double muriate of tin; the first is the salt in its crystallized state, and the others are solutions of it in water, with excess of hydrochloric acid. The consumption of these articles is very considerable. In Glasgow alone, the production of crystals of tin, in the course of a year, is estimated at from one hundred and fifty to two hundred tons; and in Manchester and its neighborhood, the annual consumption is even greater than this, being perhaps not less than from two hundred and fifty to three hundred tons.

In common with other chemical products used in the arts, these preparations of tin are of course liable to become contaminated with accidental impurities; and there is no doubt that, by some makers, they are occasionally adulterated, for the purpose of economising the tin, though the practice, PENNY is led to believe, is rarely carried to such an extent as formerly prevailed. Metallic zinc was at one time freely added in the process of dissolving the tin in hydrochloric acid, not only as a substitute for the more expensive metal, but because it assisted, as many considered, in giving to the crystals the peculiar pearly or silky lustre for which they are usually esteemed. Besides zinc, he discovered also the presence of minute quantities of arsenic, sulphates, chlorides of sodium and magnesium.

At the present time, however, he feels satisfied that the leading makers of these articles in Glasgow do not intentionally add any metallic sophistication. The principal adventitious matters contained in the crystallized chloride, are water and excess of hydrochloric acid, arising from imperfect drainage of the crystals. This is particularly the case with fibrous or feathery crystals, which have the power of retaining mechanically a considerable proportion of the mother-liquor.

The value of these preparations, as respects the several purposes to which they are applied in the tinctorial arts, depends evidently on the amount of tin they contain; it being also essential that the metal should exist exclusively in the state of protochloride.

A simple process for estimating the quantity of tin in commercial samples of these articles, has long been a desideratum among practical men. The common method for the determination of tin by the agency of nitric acid, is quite inapplicable to the analysis of the protochloride; as, during the necessary ebullition, a considerable proportion of bichloride is formed, which, from its ready volatility, would be expelled in the course of the subsequent evaporation, thereby involving a serious loss. Another method, which was submitted to repeated trials, and which was capable of giving very exact results, consists in precipitating the tin by metallic zinc, and afterwards converting it into the binoxide; but these operations are much too tedious, and involve too many nice manipulations, to be available for general purposes. The process by sulphide of hydrogen is for the same reasons even more objectionable.

The agent which PENNY proposes to employ is bichromate of potassa. Its application is based upon the fact that chromic acid, in presence of free hydrochloric acid, converts protochloride of tin into bichloride; the chromic acid becoming sesquichloride of chromium. The reaction that takes place with bichromate of potassa is represented in the following equation:—

$$3\ \mathrm{Sn\,Cl} + \mathrm{KO},\ 2\ \mathrm{Cr\,O_3} + 7\ \mathrm{H\,Cl} = 3\ \mathrm{Sn\,Cl_2} + \mathrm{K\,Cl} + \mathrm{Cr_2\,Cl_3}, + 7\ \mathrm{HO}.$$

The operations which the present process involve are easily performed, and are precisely similar to other well-known centigrade methods of analysis. A normal solution of the bichromate is added to a known quantity of the chloride of tin dissolved in water, till, on being tested with a solution of acetate of lead, a slight excess of the chrome salt is indicated by the production of yellow chromate of lead. The amount of metallic tin is then deduced from the quantity of bichromate of potassa consumed. Centigrade methods of valuation are now so extensively used, that, to scientific chemists, the necessary manipulations will at once be obvious; but as the idea is to render the process available to practical men, a detailed statement of the mode of proceeding, it is now deemed necessary to subjoin. In the first place, therefore, the operations for estimating the value of commercial specimens of crystals of tin will be described; and afterwards the process for testing the prepared liquors, called single muriate and double muriate of tin, explained. Then the results of some of Dr. PENNY'S experiments will be given, showing how he ascertained the true composition of the crystallized protochloride.

Crystals of Tin.—This salt is usually sold to the printer in jars, containing from two to three hundredweight each. A fair sample, which should not be less than one or two pounds, is taken from the bulk, and triturated in a mortar until thoroughly mixed. Very frequently this operation requires considerable attention, as the crystals, in consequence of their dampness, are apt to cake under the pestle.

One hundred grains are then weighed out, put into a basin with two ounces of water and half an ounce of hydrochloric acid, and the mixture gently heated. 83·2 grains of bichromate of potassa are next dissolved in about two ounces of tepid water, and the solution carefully transferred to an alkalimeter of one hundred measures, which is filled to the top line of the graduations by the addition of water, and then inverted on the palm of the hand for the purpose of rendering the liquid uniform throughout. This quantity of bichromate of potassa, as will be presently shown, is exactly equivalent to one hundred grains of pure metallic tin; and hence, each measure of the alkalimeter will be equivalent to one grain of the metal.

The alkalimeters in common use for centigrade analysis, are generally made of such a capacity, that one hundred measures will contain exactly one thousand grains of water; but for the present process, he found it much more convenient, as well as more conducive to accuracy, to have the instrument of double this capacity, so that the hundred measures will hold two thousand grains of water.

A solution of acetate of lead, which, to avoid repetition of words, will be called the lead test, is spotted over a white porcelain slab, placed conveniently for testing the tin solution during the next operation. It should contain at least one ounce of the acetate to eight ounces of water, and should be rendered clear by filtration. The spots on the slab must be pretty large, in order to insure excess when mixed with the chloride of tin.

The prepared solution of bichromate of potassa is now poured very cautiously into the tin solution, as in the well-known process of alkalimetry, until a drop of the latter, taken out on the end of a glass rod, and applied to the lead test on the slab, gives a faint yellow tinge. The operation is now finished. The number of measures of the chrome liquor consumed is carefully read off, and this number indicates the amount of tin in one hundred parts of the sample.

It may be as well to mention here the effects produced during the foregoing operation. On the first addition of the chrome liquor to the tin solution, sesquichloride of chromium is formed, which gives to the mixture a rich green color; and if, at this stage of the process, a drop be applied to the lead test, a white precipitate of chloride of lead will appear. These effects continue to be produced till all the protochloride of tin is converted into bichloride; but when this result is accomplished, and there is the smallest excess of bichromate of potassa, the lead test gives the yellow chromate of lead, simultaneously with the colorless chloride, and thus communicates the yellow shade, which indicates the completion of the process.

The question may here be raised, whether the indications afforded by a solution of acetate of lead, as applied in the present process, are sufficiently delicate to detect minute quantities of bichromate of potassa; and more particularly when, as in this action, there is such an abundant formation of chloride of chromium, which, by its deep green color, appears so likely to modify, or even disguise altogether, any other tint? This point was examined very minutely: in the first place, the sensitiveness of acetate of lead, spotted on a slab, in detecting bichromate of potassa dissolved in pure water was tried; and it was found that one part of the chrome salt, with ten thousand of water, gave a decidedly yellow coloring to the lead solution; with fifteen thousand of water, the yellow tint was still developed, though very slightly; and with twenty thousand, the tinge was only just perceptible. A solution of pure chloride of chromium was then added to one of the bichromate of potassa, until the mixture had a deep green hue; and after several progressive trials, PENNY was satisfied that the presence of one part of the chrome salt, even when thus colored, may be at once discovered in ten thousand of water.

These results are sufficient to show, that for indicating excess of the chrome liquor, a strong solution of acetate of lead, though used in small drops, and in presence of chloride of chromium, is an extremely delicate test; and that it may, therefore, be with confidence relied on for ordinary practical purposes. It undoubtedly requires a little practice to be able to catch the precise moment when the yellow shade is communicated; but this chemist observed that individuals previously unacquainted with the manipulations of centigrade processes, have no difficulty, after two or three trials, in deciding when the operation of adding the normal chrome solution is completed.

For the sake of convenience, the quantity of the chloride used in each operation has been limited to one hundred grains; but the process obviously possesses the advantage of being executed as easily with five hundred or one thousand, as with one hundred grains. In the analysis of commercial products, involving perhaps the valuation of many hundredweights, or even tons, the employment of large quantities is undoubtedly of essential importance; and this is more particularly the case when the processes are intended for the use of practical operators connected with chemical works.

When it is considered desirable to be very exact, PENNY recommends that forty grains of bichromate of potassa, dissolved in water, should be added to the tin solution, and that the alkalimeter should be made up with only ten grains of the chrome salt. The remaining part of the process is conducted according to the directions previously given. By this modification, it is very easy to limit the excess of chrome liquor to half a measure of the alkalimeter, which is equivalent to ·05 grains of the salt.

PENNY further states that he makes use of another test for detecting minute quantities of chromic acid and bichromate of potassa. This consists of sulphocyanide of potassium and pure protosulphate of iron, dissolved together in water, and slightly acidified with hydrochloric acid. A white slab is spotted over with this mixture, and the solution to be tested is brought into contact with it, as when acetate of lead is used. So long as the tin solution contains any protochloride of tin, little or no effect is observable upon the sulphocyanide mixture; but the moment the conversion into bichloride is complete, and there is the least excess of chromic acid in the solution, a dark-brown or red coloring is produced. The depth of the tinge depends entirely on the proportion of chromic acid present. With an extremely minute quantity, the color is brownish; but with a great excess, the tint is blood-red. It is of no consequence if a faint pinkish hue be developed on mixing the solution of sulphate of iron with that of the sulphocyanide, because, when dropped on the slab, this slight coloration becomes scarcely appreciable. This mixture is called the sulphocyanide test, which is an extremely delicate reagent. One part of bichromate in ten thousand is easily discoverable, even when the solution is colored with sesquichloride of chromium; and with pure water, one part in twenty thousand may be detected. Dr. PENNY inclines to give the preference to this test, because the coloration is more distinct, and more easily recognised, than the yellow tinge with acetate of lead; but as considerable nicety is required in the preparation of the sulphocyanide test, he is afraid it will be liable to failure in the hands of inexperienced operators.

He has also used this test very successfully in the estimation of arsenious acid by means of bichromate of potassa; but he reserves a description of its application to this purpose for a future communication.

Single Muriate and Double Muriate of Tin.—In estimating the value of these preparations, he operates somewhat differently from the process described for valuing crystals of tin. Instead of pouring the solution of bichromate of potassa into that of tin, he finds it more convenient to make up an alkalimeter with the tin liquor, and to add this gradually to a known weight of the chrome salt, dissolved in water, until the chromic acid is completely deoxidized. This result is immediately indicated when the mixture ceases to give a red coloration with the sulphocyanide test, or when it no longer produces a yellow tint with acetate of lead. In operating according to this method, it will likewise be noticed, that the gradual changes of color which the solution undergoes during the additions of the tin liquor, indicate with tolerable certainty the approach of the process towards completion. So long as there remains any appreciable quantity of the chrome salt unchanged, the solution has a yellow shade; but when deoxidation is perfect, it becomes of a rich and pure green. The necessary manipulations are as follow:—

Five hundred grains of the sample, whether single or double muriate, are poured into the alkalimeter, and sufficient water added to fill the instrument to 0°, the two liquids being well mixed by agitation.

41·6 grains of bichromate of potassa are dissolved in a basin, with two ounces of warm water and a quarter of an ounce of hydrochloric acid; and into this mixture the tin solution is poured from the alkalimeter, in small successive portions, until, on bringing a drop of it into contact with the sulphocyanide test, previously spotted on a slab, no red or dark color is seen to be produced. The number of measures consumed is read off, and on dividing one thousand by this number, one obtains the proportion of tin in one hundred parts of the sample. In a particular experiment with a specimen of double muriate, of the specific gravity 1·600, he found that, with five hundred grains in the akalimeter, 41·6 grains of the bichromate required thirty-five measures, which gave 28·57 per cent. of tin; with a sample of single muriate, specific gravity 1·422, 47·5 alkalimetrical measures were consumed, equivalent to 21 per cent. of tin.

Great care should be taken that the bichromate of potassa employed in these processes is perfectly pure. As usually sold it is quite unfit for the purpose, in consequence of a large admixture of sulphate of potassa; it may, however, be easily purified by two or three crystallizations; and previous to being used, it should be finely powdered, and heated to incipient fusion.—*Penny.*

The sesquichloride of tin may be prepared by putting into a solution of protochloride of tin a quantity of newly precipitated sesquioxide of iron, when a double decomposition takes place. Two parts of protochloride of tin, and one part of the sesquioxide, give two of protochloride of iron and one of sesquioxide of tin; for example—

$$2\,(Sn\,Cl) + Fe_2\,O_3 = Sn_2\,O_3 + 2\,(Fe\,Cl).$$

This sesquioxide is precipitated, collected, washed free of iron, and then redissolved in hydrochloric acid, forming a sesquisalt of tin. This oxide has several distinctive properties in its reaction with other matters; and in many practical operations in dyeing, it is more than probable that this class of salts plays an important part. It will be seen, under the head IRON in this article, that some of the blues there mentioned are, in all probability, dependent upon the formation of this salt for their peculiar tint.

Persalts of tin are produced by the solution of the binoxide in an acid. The principal acid salt of this sort used in the dye-house is the bichloride. When tin is dissolved in hydrochloric acid, with nitric acid present, and the temperature is allowed to rise, a bichloride will be formed. Dyers, in dissolving for mordants, generally use a mixture of hydrochloric and nitric acids. If care be taken to keep the solution cool, a protochloride is formed, notwithstanding the presence of nitric acid; but should tin be added in too great quantity at a time, the heat will be so much increased by the rapid action that a bichloride will be the result; and there is often produced, in the preparation of these salts, a mixture of protosalts, sesquisalts, and persalts. Hence, says NAPIER, the cause of the irregularity of tint produced by tin mordants thus prepared; and he advises that very great care be taken in the preparation of such salts. Bichloride is often desirable as a mordant, and in that case it may be prepared by dissolving some crystals of the salts of tin, or a quantity of single or double muriate, and passing through the solution a current of chlorine gas—see CHLORINE—or by heating the solution, and adding to it when hot some nitric acid. Care must be taken, in this last process, not to add the acid in too great quantity at a time, as violent effervescence ensues, and the contents will boil over, causing loss. The technical name of the bichloride is *oxychloride.*

The acid preparations of tin used in dyeing are called *spirits,* with a term prefixed to each, denoting their particular application, as red spirits, barwood spirits, plumb spirits, *et cetera.* Their preparation is performed by melting the tin in an iron pot, and pouring the metal from some height into a vessel filled with cold water, which granulates the tin into lamellar masses. This process is termed *feathering* the tin.

Red Spirits are made by mixing together, in a stoneware vessel, three parts by measure of hydrochloric acid, one part nitric acid, and one part water, and adding to this in small quantities at a time feathered tin, till about two ounces of tin to the pound of the acid used is dissolved. In this operation the temperature should not be allowed to rise.

Yellow Spirits are prepared in the same way, the only difference being, that sulphuric acid is used instead of the nitric. This spirit is used for dyeing yellow by bark, as described under QUERCITRON, page 623; but red spirits are equally good for the same purpose. The only advantage of employing the yellow spirit consists in the economy of using sulphuric instead of nitric acid.

Barwood Spirit is prepared by using five measures of hydrochloric acid, one nitric acid, and one water, dissolving in this one ounce of tin for every pound of the whole mixture. One and a half ounce of tin may be used if the red to be dyed be required very deep.—See BARWOOD, page 572.

Plumb Spirit is prepared by using from six to seven measures of hydrochloric acid to one nitric acid and one water, dissolving in it one and a half ounce of tin for each pound of the acid mixture. This spirit is named from a preparation made with it and a decoction of logwood. A strong solution of that wood is prepared and allowed to cool; after which there is added to each gallon of the solution from a pint to a pint and a half of the spirit; the whole is well stirred and set aside to settle. This preparation has a beautiful violet color; and silk and cotton are dyed of that shade by dipping them into the plumb liquor, without any previous mordant. Of course the depth of tint will correspond to the strength of the solution. Spirit for woollen dyeing is prepared by adding tin to nitric acid, in which a quantity of chloride of ammonium has been dissolved.

All these spirit preparations are varied by different operators, some preferring more or less of the two acids, and also of the tin; but the proportions given form good working spirits, and if care be taken in their preparation not to *fire* them, that is, not to allow the temperature to get so high as to convert the tin into a persalt, the operator will not fail in his processes, as far as the quality of the spirit is concerned.

Acetates and oxalates of tin are also used occasionally for dyeing purposes, by adding a solution of acetate of soda or potassa to chloride of tin for the acetate, and a solution of oxalate of soda or potassa for the oxalate of tin. In both cases a double decomposition takes place, the chlorine combining with the alkali and the acid with the tin. The reactions and precipitates of the acid salts of tin, with other reagents, are as follow:—

	Protosalts.	Persalts.
Potassa and soda,	White, soluble in excess,	White, soluble in excess.
Ammonia,	White, insoluble in excess,	White, soluble in excess.
Carbonate of the alkalies,	White, soluble in caustic alkalies,	White, soluble in caustic alkalies.
Yellow prussiate,	White,	None.
Red prussiate,	White,	None.
Galls,	Slight yellow,	None.
Gold,	Deep purple,	None.
Sulphurets of the alkalies,	Brown,	Yellow, soluble in caustic potassa.

Besides these acid salts of tin just described, there is a series of alkaline salts, in which the binoxide of tin combines with alkalies in the same manner as an acid, and forms definite compounds, named stannates. The stannate of soda has been of late years extensively used as a dyeing agent. The mode of its preparation has been the subject of several patents. The general method is to fuse the oxide of tin with soda, either caustic or carbonate, at a red heat, then dissolving the fused mass in water, and crystallizing. When metallic tin is used instead of oxide, a quantity of nitrate of potassa is put in with the alkali, which by decomposition converts the tin into an oxide. The following extracts from the specification of Mr. JAMES YOUNG's patent, will give a general idea of the methods by which such salts are to be prepared, including stannates and stannites of the alkalies:—

Firstly: To make stannate of soda, he puts a quantity of tin ore, or what is commonly known in Cornwall by the name of *black tin*, reduced to powder, into an iron pot, along with a solution of caustic soda, and sets the pot on a fire to boil. The proportions in which he uses these ingredients vary with their respective qualities. If the ore contain 70 per cent. of tin, he employs about two and a half times its weight of caustic soda liquor, containing about 22 per cent. of soda, increasing or diminishing the proportion of the liquor employed, according as it is desired to produce a stannate with a greater or less excess of alkali. The materials are kept well stirred, and the heat gradually raised up to between 500° and 600° Fahr., at which temperature the ore is acted upon by the soda, and the tin or oxide of tin contained therein, or the greater part thereof, combines with the alkali. The progress of the operation may be known from time to time, by taking out of the pot a small portion of the mass, and ascertaining how much of it dissolves in water, and how much of the ore has been left unacted upon. The hot mass is then transferred from the pot to another vessel, and set to cool. And when cooled it is mixed with water, when any insoluble matters which may have remained in it, unaffected by the caustic soda, are easily separated by filtration or by subsidence. The clear liquor which remains is the stannate required, which may be either employed in that state or evaporated to dryness, or crystallized, the solid salt being dissolved as required for use.

Secondly: This chemist also prepares stannate of soda by mixing a quantity of tin ore, reduced to powder, with one and a half times its weight of nitrate of soda, subjecting the mixture to a red heat in an iron vessel, passing a current of steam over it, and keeping it constantly stirred during the operation, in order to expose fresh portions of it to the action of the steam. Nitric and nitrous acids are given off in fumes, which may be condensed with water, and collected as collateral products—reducing thereby the cost of the stannate. Stannate remains, which may be freed from its insoluble impurities by mixing it with water, and filtration or subsidence, as in the process first before described; and it may be also left either in a state of solution, or crystallized or evaporated, as aforesaid.

Thirdly: He substitutes for the nitrate of soda employed in the last preceding process chloride of sodium —common salt—using, however, equal weights of the salt and tin ore; and pursuing the same method in all other respects, he also obtains thereby stannate of soda, with hydrochloric acid as the collateral product.

Fourthly. He procures by the following process both stannite of soda and stannate of soda. He subjects to a red heat a quantity of metallic tin, mixed with an equal weight of solid hydrate of caustic soda—which may be obtained by boiling down caustic soda liquor, say three and a half hundredweight of the liquor containing 22 per cent. of soda to about one hundredweight of the hydrate—stirring the materials well during the operation; whereupon the water of the hydrate of soda becomes decomposed, and parts with its oxygen to the tin, and the oxide of tin so formed, uniting with the soda, forms a stannite of soda, suitable for some dyeing and printing purposes. To convert this stannite of soda into a stannate of soda, it is boiled in water, on which a portion of metallic tin is precipitated in the form of a black powder, and the solution remaining is stannate of soda. Or, twenty parts of metallic tin are taken, sixteen parts of solid hydrate of caustic soda, and three parts of oxide of manganese, all by weight, and subjected to a red heat in an open pot, keeping the mixture constantly agitated, and allowing a free access of air. So small a portion of oxide of manganese as is contained in this mixture would be quite insufficient of itself to further oxidize all the tin, but this oxide of manganese is converted by the heat and absorption of oxygen from the atmosphere, into a manganate of soda, which salt becomes decomposed by the tin, and part of it goes to form binoxide of tin, leaving a residuum of oxide of manganese; this becomes once more, by a new absorption of atmospheric oxygen, a manganate, which is decomposed by the tin as before, yielding a fresh accession of binoxide of tin; and so the process goes on until all, or nearly all, the tin has become stannic acid and combined with the soda. The mass in the pot is then dissolved in water, and the solution clarified by filtration or subsidence. The supernatant liquid is a solution of stannate of soda, which may be either left as it is, or crystallized, or evaporated to dryness, as aforesaid. The precipitated oxide of manganese may be collected and used over again for the same purpose.

The stannite formed in the first of the processes described under this branch of Young's specification, may be changed into stannate of soda by merely keeping it freely exposed, at a red heat, to the atmosphere for a sufficient length of time; but preference is given to manganese as the oxidizing agent, being more expeditious, and, on the whole, cheaper.

Fifthly: He also employs for the formation of stannate of soda, oxide of tin, which is obtained by heating metallic tin to redness in an iron vessel, keeping it well stirred, and passing a current of steam or air over it. And this oxide of tin is treated, along with caustic soda, in precisely the same way as the ore has been before directed to be managed.

Sixthly: Stannate of potassa is manufactured by each and every of the methods before described of manufacturing stannate of soda, substituting only in each case where caustic soda, or nitrate of soda, or chloride of sodium is directed to be employed, an equivalent of caustic potassa, or of nitrate of potassa, or of the chloride of potassium, as the case may be.

Seventhly: This chemist also manufactures stannite of potassa by the same process as stannite of soda as before directed to be produced, substituting for the hydrate of soda an equivalent of hydrate of potassa.—*Young.*

Another preparation of tin with alkalies has been introduced into dyeing operations—a double salt of soda with arsenic and stannic acids, termed arseno-stannate, or arseno-stannite of soda. Reference has already been made by extract from Napier's Manual, to the questionable practice of working with such deadly poisons as articles of common use in a factory. And unless applied to some purpose, for which no substitute could be used with anything like the same advantage, their use should be avoided. At all events, a higher motive should exist than mere economy in producing a certain tint upon a dyed or printed article. On the chemical constitution and practical application of this salt, the researches of E. Haeffely, read at the meeting of the British Association in Glasgow, in September, 1855, are here quoted:—

By pouring an excess of nitric acid into a solution of stannate of soda and arseniate of soda, in which the arseniate predominates, and bringing this mixture to a state of ebullition, a white gelatinous precipitate is produced, composed of arsenic acid, binoxide of tin, and water; when washed and dried at the ordinary temperature, it forms transparent fragments.

To analyse the above compound, the delicate process described by M. Levol was employed, namely, placing within a glass tube heated to redness, one hundred parts in an anhydrous state, and passing through it a current of hydrogen, when the tin is left in the metallic form, and the arsenic is sublimed in the tube.

Three analyses gave:—

Tin,..........	45	46·3	45·21
Arsenic,.......	27·2	26·3	—

By adding to these numbers the respective quantities of oxygen required for their maximum oxidation, the formula is arrived at—

$$2\ Sn\ O_2\ As\ O_5,$$

which requires

Tin,.......... 44·52 | Arsenic,....... 28·31

Dried in the stove at 248°, the loss amounted to 25·3 per cent., corresponding to 10 equivalents.

To a known weight of a commercial stannate, of a a known quantity of arseniate of soda, boiled with an excess of nitric acid, was added the insoluble arseniate of tin, $2\ Sn\ O_2\ As\ O_5$, and from its weight the amount of arsenic acid and binoxide of tin calculated. The liquid filtrates are then treated with sulphide of hydrogen, to throw down, as sulphide of arsenic, the excess of arsenic acid added intentionally. The amount of arsenic acid found, and the amount added intentionally being known, it will be easy to calculate the original quantity which the stannate contained.

Decomposition of $2\ Sn\ O_2\ As\ O_5 + 10$ aq.—In presence of an excess of a fixed alkali, this arseniate of tin is split into two different soda salts, one of which contains all the arsenic, and crystallizes at first in silky needles, while the mother liquor consists of ordinary stannate of soda; the reaction takes place according to the equation—

$$2\ (2\ Sn\ O_2,\ As\ O_5) + 8\ Na\ O = 2\ (Sn\ O_2\ As\ O_5)\ 6\ Na\ O + 2\ (Na\ O\ Sn\ O_2).$$

This same salt is also obtained by boiling two equivalents of tribasic arseniate of soda with one equivalent of hydrated binoxide of tin. When hydrate of alumina is taken, an arseniate of alumina and soda is obtained.

To analyse the tin salt, each constituent was determined by direct processes. A current of hot air deprived of its carbonic acid, passed over one hundred parts of the salt, gave a loss of 48 per cent. of water. One hundred parts treated with an excess of boiling nitric acid, gave 13·95 parts of the insoluble arseniate of tin, which contained 7·887 parts of binoxide, combined with 6·063 of arsenic acid. One hundred parts acidulated with hydrochloric acid, treated with a current of sulphide of hydrogen, gave 41·5 parts of double sulphide of tin and arsenic.

These two weights being ascertained, a mere calculation may be substituted for the tedious operation of M. LEVOL, for it remains only to calculate the corresponding amount of double sulphides which 13·95 parts of arseniate of tin would form, to be deducted from the total amount of double sulphide, 41·5, obtained; as follows:—13·95 of $2\ Sn\ O_2\ As\ O_5 = 15{\cdot}825 = 2\ Sn\ S_2\ As\ S_5$; and 15·825 $2\ Sn\ S_2\ As\ S_5$, deducted from 41·5 double sulphide, leaves 25·675 of $As\ S_5 = 19{\cdot}05\ As\ O_5$.

By evaporating to dryness the hydrochloric acid filtrates, 37 of chloride of sodium = 19·6 soda are obtained.

Recapitulation of the numbers:—

	At. Weight.	Theory.	Haeffely.
3 Eqs. Binoxide of tin,	93	7·970	7·887
½ Eq. Soda,	37·5	19·766	19·600
1 Eq. Arsenic acid,	115	24·442	25·113
25 Eqs. Water,	225	47·822	48·000
	470 5	100·000	100·600

The formula of this salt is therefore—

$$6\ Sn\ O_2,\ Na\ O,\ 2\ As\ O_5 + 5\ H\ O.$$

Stannate of soda is used as a mordant in print and dye works. Numerous experiments have been made with it on a large scale, to decide whether, in calico printing or dyeing, the hydrated binoxide of tin alone would be preferable to an arseniate of the same oxide as a mordant. The result of comparative trials leads to the preference of hydrated binoxide of tin alone, the various shades being more brilliant and less liable to unevenness than when arsenic acid is present. It would be desirable to substitute, in commerce, a purer stannate of soda for that at present sold, as well as for that containing arseniate of soda.

ZINC.—The only salt of this metal seen in the dye-house is the sulphate—white copperas, or white vitriol—and even this is not used to any great extent, nor for the direct purpose of a dye or mordant, but for certain qualities which the oxide possesses in reacting upon other mordants; and as the precipitate with zinc salts are mostly all white, the sulphate is occasionally used to modify the action of stronger agents, by a double decomposition, where the oxide formed does not affect the tint, as in bichromate of potassa in dyeing yellows. Further, as it parts with a portion of its oxygen when in contact with deoxidizing agents, it is made to serve a purpose in some of the processes in calico-printing. For the chemical character of this metal and its salts, see under article ZINC, in the general arrangement of this work.

PRACTICAL OPERATIONS.—For the substance of the following practical operations of the dye-house, the Editor is greatly indebted to NAPIER'S Manual of Dyeing Receipts.

Decoctions of the different woods are prepared for general use in the dye-house as they are required. If the wood be in the chipped state, it must be boiled for an hour, the proportion used being one pound of wood to the gallon of decoction; a second boiling is generally given with new water, and the liquor obtained used instead of water with more new wood. This second liquor is not good for dyeing alone, but when employed instead of water for new wood, three quarters of a pound per gallon of decoction of the new wood is sufficient. The second liquor may be used, however, as an auxiliary in the dyeing of compound colors, such as browns, drabs, and fawns. If the wood be ground, the same quantity is taken—namely, one pound for each gallon of decoction required, and is prepared as follows:—On a piece of coarse cloth stretched upon a frame or laid into a basket, put the ground wood, and place it over a vessel, then pour over the wood boiling water, until the percolations are nearly colorless.

Barwood and camwood are always used in the ground state, the wood being put into the boiler along with the goods; no decoctions of these woods are made. Decoctions of bark and weld are often formed by putting them into a coarse canvas bag, and then suspending it in boiling water.

To Prepare Annotta.—Into two gallons of water put one pound annotta, four ounces pearl-ash, and two ounces soft soap, and apply heat, and stir until the whole is dissolved. When convenient, it is best to boil the solution.

To Prepare Catechu.—To seven or eight gallons of water put one pound of catechu, and boil till all is dissolved; then add two ounces of sulphate of copper, and stir, when it is ready for use. Nitrate of copper may also be used, taking one wine-glassful of the solution prepared as under:—To one part by measure nitric acid, and two parts water, add metallic copper so long as the acid will dissolve it; then bottle the solution for use.

To Make Sulphate of Indigo.—Into five pounds of the most concentrated sulphuric acid, stir in by degrees one pound of the best indigo finely ground; expose this mixture to a heat of about 160° Fahr. for ten or twelve hours, stirring it occasionally; a little rubbed upon a window pane should assume a purple-blue color.

This preparation is now sold in the market in the state of a paste, under the name of *Indigo Extract*, which is prepared by proceeding exactly as stated for sulphate of indigo, and then diluted with about four gallons of hot water, and the whole put upon a thick woollen filter, over a large vessel, and hot water poured upon the filter, until it passes through nearly colorless; the blackish matter retained upon the filter is thrown away, and the solution passed through is transferred to a leaden vessel, and evaporated to about three gallons, to which is added about four pounds chloride of sodium, and well stirred; the whole is again put upon a woollen filter, and allowed to drain. The extract remains as a thin pasty mass upon the filter, and is ready for use.

To Make Red Liquor.—Into one gallon hot water place two pounds of alum; dissolve, in a separate vessel, two pounds acetate of lead in one gallon water;

in a third vessel dissolve half a pound crystallized soda; mix all the solutions together, and stir well for some time, then allow to stand overnight; decant the clear solution, which is ready for use.

Other proportions for making this mordant are given at page 37.

To Make Caustic Potassa.—To three gallons of water add two pounds either black or pearl ashes, and boil; when seething, add newly-slaked lime, until a small quantity taken out does not effervesce when an acid is added to it. To do this, take a tumbler half-filled with cold water, take out a table-spoonful of the boiling lie, and put into the tumbler, and add a few drops of sulphuric acid; were sulphuric acid added to the hot lie, it would spurt up and endanger the operator. When the addition of acid causes no effervescence, the boiling and adding of lime is stopped, and the whole allowed to settle; then remove the clear into a vessel having a cover, to prevent it taking carbonic acid from the air. This serves as a stock for general use. The lime sediment remaining may have some hot water added, which will give a strong lie, and may be used for first boils for yarn or heavy cloth.

To Make Caustic Soda.—For every gallon of water add one pound of soda ash, or two pounds of crystallized soda of the shops; boil, and proceed by adding slaked lime, and testing as for potassa; boiling for some time is essential to insure causticity.

To Make Lime-Water.—Take some well and newly-burned limestone, and pour over it some water so long as the stone seems to absorb it, and allow it to stand; if not breaking down freely, sprinkle a little more water over it. A small quantity is best done in a vessel, as an old cask, in which case it may be covered with a board or bag. After being slaked, add about one pound of this to every ten gallons of cold water, then stir well and allow to settle; the clear liquor is what is used for dyeing. This should be made up just previous to using, as lime-water standing attracts carbonic acid from the air, which tends to weaken the solution.

To Make Bleaching Liquor.—Take a quantity of bleaching powder, and add to it as much water as will make it into a thin cream; take a flat piece of wood, and break all the small pieces by pressing them against the side of the vessel, then add two gallons of cold water for every pound of powder; stir well, put a cover upon the vessel, and allow the whole to settle. This will form a sort of stock vat for bleaching operations.

To Make a Sour.—To every gallon of water add one gill of sulphuric acid, stir thoroughly; goods steeped in this should be covered with the liquor, as pieces exposed become dry, which deteriorates the fibre; if left under the liquor, the cloth is not hurt by being long in the sour; but on being taken out every care should be taken to wash out the liquor thoroughly, otherwise the goods will be made tender.

To Make Cochineal Liquor or Paste.—Put eight ounces ground cochineal into a bottle, and add to it eight ounces, by measure, ammonia, and eight ounces water; let the whole simmer together for a few hours, when the liquor is ready for use.

To Make Iron Liquor.—See *Acetate of Iron*, page 42; or small quantities may be made as follows:—Put pieces of iron, or filings, into pyroligneous acid, and allow it to stand for several days, stirring occasionally; a gentle heat assists the action.

To Make up a Blue Vat.—Take one pound of indigo, and grind in water until no grittiness can be felt between the fingers; put this into a deep vessel—casks are generally used—with about twelve gallons of water; then add two pounds copperas, and three pounds newly-slaked lime, and stir for fifteen minutes; stir again after two hours, and repeat every two hours for five or six times; towards the end, the liquor should be of a greenish-yellow color, with blackish veins through it, and a rich froth of indigo on the surface. After standing eight hours to settle, the vat is fit to use.

To Make Spirits or Tin Preparations.—On this subject, see *Tin*, in the present article, page 653.

For Copperas.—See *Iron Salts*, page 646.

For Blue-Stone—sulphate of copper.—See *Copper Salts*, page 555.

In making solutions of these salts, such as copperas, blue-stone, chrome, *et cetera*, there is no fixed rule to be followed. A quantity of the crystals are put into a vessel, and boiling water poured upon them, and stirred till dissolved. Some salts require more water than others when saturated solutions are wanted; but in the dye-house a certain degree of saturation is not essential, and therefore there is always used ample water to dissolve the salt. In all cases, however, the proportions are known, so that the operator, when adding a gallon or any quantity of liquor to the dye bath, knows how much salt that portion contains. From half a pound to one pound per gallon is a common quantity.

To Remove Oil Stains.—When oil spots are upon goods, and so fixed or dried in, that steeping in an alkaline lie will not remove them, rub a little soft soap upon the oil stain, and let it remain for an hour, then rub gently with the hand in a lather of soap, slightly warmed, and then wash in water; for cotton, a little caustic lie will do equally well for removing the oil, but the soap is the preferable process, and seldom fails. It is essential that all oil or grease be removed before dyeing.

To Remove Iron Stains.—Take a little hydrochloric acid in a basin or saucer, and make it slightly warm, then dip the iron stain into the acid for about one minute, which will dissolve the oxide of iron; the cloth must be well washed from this, first in water, then in a little soda and water, so as to remove all trace of acid. A little oxalic acid may be used instead of hydrochloric, but more time is required, and with old fixed spots is not so effective. The same precautions are necessary in washing out the acid, as oxalic acid dried in the cloth injures it.

To Remove Mildew from Cotton.—Proceed with the stains by rubbing in soap or steeping in a little soda, washing, and then steeping in bleaching liquor same as in the process of bleaching, or by putting a wine-glassful of the stock liquor as prepared above in one pint of water, afterwards wash, and pass through a sour, and wash.

To Remove Indelible Ink Marks.—Steep the marking in a little chlorine water, or a weak solution of bleaching liquor, for about half an hour, then wash in ammonia water, which will obliterate the stain; the goods to be washed from this in clean water. Or they may also be removed by spreading the cloth with the ink mark over a basin filled with hot water, then moisten the ink mark with the tincture of iodine, and immediately after take a feather and moisten the parts stained by the iodine, with a solution of hyposulphite of soda, or caustic potassa or soda, until the color is removed, then let the cloth dip into the hot water; after a while wash well, and dry.

To Detect Animal and Vegetal Fibres.—Treat the fabric with bichloride of tin heated to from 130° to 150° Fahr., when the cotton and linen become black, and wool and silk remain unchanged.

To Detect Mixed Fabrics of Cotton and Wool.—Dip a piece of the suspected cloth in bleaching liquor; after a little the woollen turns yellow and the cotton white, and consequently may be easily distinguished.

To Detect Cotton in Linen.—The piece to be tested is boiled to remove all dressing, and then dried; a portion of the piece is put into common vitriol for about one minute, it is then taken out, washed in water several times, and then in a weak solution of soda or potash, and all gummy matter formed is removed by gentle rubbing; by this process the cotton is dissolved out and the linen remains, or what portion of the cotton is not dissolved becomes opaque white, the linen is transparent, and is thus easily detected. By comparing the portion of cloth immersed with a similar portion not tried, the quantity of cotton present may easily be estimated.

Another method for Detecting Cotton in Linen.—Take a small piece of the cloth, boil in water and dry; then take three parts, by weight, of sulphuric acid, and two parts of crushed nitrate of potassa; the dry piece of cloth is put into this for six or seven minutes, and then washed from this till there is no taste of acid; dry at a gentle heat; then put it into a mixture of ether and alcohol, which will dissolve the cotton and not the linen. If the piece be weighed before putting into the ether and alcohol, and after, the quantity of cotton in the fabric may be thus ascertained.

Cotton and Wool.—Take a small piece of the cloth and boil in caustic soda, when the wool will be dissolved and the cotton remain. If the threads have been previously counted, their relative mixture may be thus ascertained.

Cotton with Silk and Wool.—Put a piece of the cloth into chlorine water or bleaching liquor. The cotton is whitened by the liquor, and the silk and woollen become yellow. These changes will be easily distinguished by the use of a small pocket lens.

Another method.—Take a small piece and unravel the threads, and inflame them; the cotton burns away freely, with little or no black charcoal; the woollen and silk shrivel up, leave a black charcoal, and give a strong smell.

To prepare Cotton Yarn for Dyeing.—Cotton is generally brought to the dye-house in bundles of five pounds or ten pounds, made up of *heads*, each head having ten hanks, except when the yarn is very coarse, when each head has only six hanks; or very fine, when each head has twenty hanks. The number of heads indicates the grist of the thread, called *the number.* Thus, ten pounds of No. 60 will have sixty heads of ten hanks, or thirty heads of twenty hanks. These heads are made up into spindles of eighteen hanks by the dyer, and through each spindle is tied a piece of stout thread or twine, termed a band; the bundle, when banded, is divided into four or six quantities, and rolled up and tied into bundles for boiling. Thus, No. 60 will give thirty-five spindles and twelve hanks, equal to thirty-six, and will be rolled up into six sixes, or all sixes, as it is termed, or four nines, ten pounds being invariably named a bundle.

After banding, cotton is boiled in water for two or three hours until thoroughly wet. The bundles are then loosed, and each roll of yarn is put upon a wooden pin, about three feet in length and about one and a half inch thick, six pins or sticks forming a bundle, or four sticks, according to the division made by the bander.

If the color to be dyed be dark—such as brown, black, orange, deep blue, *et cetera*—the yarn is now ready for the dyeing operation; but if for light shades—such as pink, sky-blue, *et cetera*—the yarn must be bleached previous to being dyed, which is done thus:—

A vessel sufficiently large to allow of the cotton being wrought in it freely without pressing, is to be filled about two-thirds with boiling water; add a pint of bleaching liquor from the solution made up as described above for every gallon of water in the vessel, then work the yarn in this for half an hour. Into another vessel of similar size, filled two-thirds with cold water, add a wine-glassful of sulphuric acid for every two gallons of water; stir well, and then put the yarn from the bleaching solution into this and work ten minutes, and then wash from this until all acid is removed.

This, in general, will produce a white of sufficient purity for all light shades.

But if the cotton has to be finished white, in that case the process is conducted as under:—

The yarn when banded is boiled for three hours in caustic lie, either potassa or soda, made by adding one gill of the caustic lie, prepared as described above, for each gallon of water in the boiler; wash well from this lie, and lay the yarn to steep in a bleaching liquor, made up as in last receipt, but with cold water; after four or five hours, lift and steep for an hour in a sour of one wine-glassful of vitriol to the gallon water, lift and wash well, then boil again in a lie of half the strength of the first for two hours, and wash from this, and steep again four hours in bleaching liquor; wash from this, and steep for an hour in a clean sour; wash well from this, and dry. A little smalt blue is put into the last washing water to clear the white.

To prepare Cotton Cloth for Dyeing.—The cloth is taken out of the fold and hanked up by the hand, taking the end through the hank and tying it loosely, technically termed *kinching;* it is then steeped in old alkaline lie overnight, which loosens and removes the oil, grease, and dressing which it has obtained in weaving; it is then thoroughly affused in clean water. Where there is a dash wheel, it should be used for this washing.

From these liquors often fermenting with the paste in the cloth, this process has been technically termed the *rot steep.*

If the colors required upon the goods be dark, no other preparation is necessary; but if light, the cloth has to be bleached, which is done by boiling after the *rot steep* in caustic lie, of the strength of one gill of stock lie to the gallon of water, for three hours; wash out the boil, and steep in bleaching liquor for six hours, same strength as given for yarn; wash, and steep an hour in a strong sour of one wine-glassful of sulphuric acid to the gallon of water; wash well from this before drying or dyeing. If the cloth be very heavy, one operation may not be enough; in such cases proceed as at the beginning, by boiling, steeping, and souring. In bleaching cloth for dyeing, care has to be taken that it is all equally white, otherwise it will show in the color.

If the goods be old, and have been previously dyed, and if the shade required be a deep shade, and the color of the goods light, in that case nothing is generally required but steeping to remove any grease or starch; but if the dye upon the cloth be dark, the best method is to proceed as if they were grey goods, and subject them to a process of bleaching. The quantity of water used in the operation is simply as much as will allow the pieces or the yarn ample room to be put under the fluid easily without pressure.

RECEIPTS.—In the following receipts, the quantity of stuffs given is for ten pounds of cotton, whether yarn or cloth. Of course any quantity may be dyed by proportioning the dyeing materials to the fabric; but when small articles are dyed—such as ribbons, gloves, handkerchiefs, or a dress—a little more of the stuff may be used without affecting the general tint of the color, as small quantities cannot be dyed with the same economy as on the large scale. Where washing is referred to, it is always in cold water, unless hot be mentioned.

1. *Common Black.*—Steep the goods in a decoction of three pounds sumach while it is hot, and let them lie overnight; wring out and work for ten minutes through lime-water, then work for half an hour in a solution of two pounds copperas. They may either be washed from this, or wrought again through lime-water for ten minutes—the former gives the preferable shade, but must be well affused; work them for half an hour in a warm decoction of three pounds logwood, adding a half-pint of chamber lie; before entering the goods, lift and raise with two ounces of copperas in solution; work ten minutes, then wash and dry.

2. *Jet Black.*—The goods are proceeded with exactly as last; but along with the logwood is added one pound fustic, and finished as above.

In both these blacks, if three pints iron liquor be used instead of the copperas, or in part mixed with the copperas, it makes a richer shade of black, but copperas is most generally used; if mixed, use half the quantity of each.

3. *Blue Black.*—Dye the goods first a good shade of blue by the vat, and then proceed exactly as for common black; but should the blue be very deep, as is often the case, then half the quantity of the materials given above will suffice.

4. *Spirit Brown.*—The goods are dyed first a spirit yellow, exactly as at page 623, and washed; they are then wrought for half an hour in a decoction of two pounds lima or peach wood and one pound logwood; lift up and add three ounces of alum in solution, and work fifteen minutes; wash and dry. By varying the proportions of logwood and limawood, a variety of shades can be produced.

5. *Mordant Brown.*—Dye a yellow, the same as at page 624, then work for half an hour through a decoction of two pounds limawood and eight ounces logwood, lift and raise with two ounces alum in solution; work for fifteen minutes, and wash and dry.

This method is well adapted for cloth goods, is better than the spirits, and more easily performed by the non-practical man. The spirit brown is best for yarn.

6. *Cinnamon Brown.*—Dye a dark spirit-yellow, the same as at page 623, and work for twenty minutes in three pounds and a half limawood and half a pound logwood; then raise, by adding two ounces of alum in solution; wash in cold water, and dry.

7. *Uvanterin Brown.*—Dye a spirit-yellow, the same as at page 623, and then work for twenty minutes in a decoction of one pound limawood and one pound fustic; lift and raise, by adding half-pint red liquor, as at page 656; work ten minutes in this; wash in cold water, and dry.

8. *Fawn Brown.*—Take one part annotta liquor—page 656—and one part boiling water; stir well, and work the goods in this for ten minutes; wring out and wash in two waters; then work for twenty minutes in a decoction of two pounds fustic and one pound sumach; lift and add three ounces copperas in solution; stir well, and work for twenty minutes longer; wash from this in two waters; then work for twenty minutes in a decoction of eight ounces limawood, eight ounces fustic, and four ounces logwood; lift, and raise with one ounce alum; work ten minutes; wring out, and dry.

9. *Catechu Brown.*—Work the goods at a boiling heat for two hours, or steep for several hours if the liquor is allowed to cool, in two pounds catechu, prepared as at page 656; wring out, and then work for half an hour in a hot solution of six ounces bichromate of potassa; wash from this in hot water. If a little soap be added to the washing water, the color is improved.

Any depth of shade of brown may be dyed by repeating the operation.

10. *Catechu Chocolates.*—Dye a brown, as last, then work fifteen minutes in a decoction of one and a half pounds logwood; lift, and add three ounces alum in solution; work ten minutes longer; wash out, and dry.

By this process, a great variety of browns and chocolates may be produced, both by using different quantities of logwood, and by different depths of brown before the logwood is applied.

11. *Chocolate or French Brown.*—Dye a spirit-yellow, as at page 623, then work for half an hour in a decoction of three pounds logwood; lift, and raise with half a pint of red liquor, and work ten minutes longer; wash and dry.

Another shade of deeper chocolate will be obtained by adding one pound fustic with the logwood.

12. *Catechu Fawns.*—Work the goods fifteen minutes in hot water, to which has been added two pints of the catechu—page 656; wring from this, and work fifteen minutes in hot water, in which has been dissolved one ounce of bichromate of potassa; wash from this, and dry.

13. *Catechu Fawns—Another method.*—Work in the solution of catechu the same as last; wring out, and then work for fifteen minutes in warm water, to which has been added two ounces acetate of lead previously dissolved; wash in cold water, and dry.

14. *Catechu Fawns—Another method.*—Work for fifteen minutes in warm water, to which has been added four pints of catechu—page 656; lift, and add two ounces copperas in solution, and work for other fifteen minutes; wash from this in one tub water, and finish through warm water, in which as much soap has been dissolved as will raise a lather, and dry out.

For *Pinks*, *Roses*, *et cetera*, see SAFFLOWER, p. 626.

15. *Common Red.*—Put the goods into a decoction of three pounds sumach as soon as possible after being made, and let them steep till the liquor is cold, say overnight; wring out, and work for an hour in red spirits diluted to from 2° to 2·5° Twaddle's hydrometer, or about one gill spirits, page 653, to each gallon water; wring out, and wash well, and make a decoction of three pounds limawood and one pound fustic; work the goods in this for half an hour at a heat that the hand may be held in without pain, lift up and raise by adding one gill red spirits; return the goods, and work fifteen minutes longer; wash out, and dry.

16. *Barwood Red.*—To a decoction of two pounds sumach add a wine-glassful of vitriol, and steep the goods in this decoction for at least six hours; wring out and work in spirits, diluted to 2·5° Twaddle, for an hour; wring out and wash, then pass through a tub of warm water; put ten pounds of barwood into a boiler with water, and bring it near to the boil, into which the goods are entered and wrought amongst the wood grains for about three quarters of an hour; lift out, wash, wring, and dry. Deeper shades may be dyed by using greater quantities of stuffs in each operation.

17. *Common Crimson.*—To a decoction of three pounds sumach, the goods steeped in it overnight, and then spirited at 2° Twaddle; wash and work through a decoction of three pounds limawood and one pound logwood for thirty minutes, then raise with a gill of red spirits; work for fifteen minutes more; wash out, and finish.

By using only limawood without logwood, a beautiful red crimson is obtained, and by varying the proportions and quantities, a great diversity of tints will be dyed by the same proportion of sumach and spirits.

18. *Light Straw.*—To a tub of cold water add four ounces of acetate of lead, previously dissolved, work the goods through this for fifteen minutes, and wring out; into another tub of water add two ounces of bichromate of potassa; work the goods through this ten minutes, wring out, and pass again through the lead solution for ten minutes; wash, and dry.

19. *Leghorn.*—Proceed and finish exactly as last, but along with the chrome add a half-pint annotta liquor.

Different depths and tints may be obtained by using more or less of these stuffs, without varying the mode of working.

Other receipts are given for dyeing chrome yellows, oranges, *et cetera*, at page 644.

20. *Annotta Orange.*—Heat the annotta solution—page 656—to working heat—about 140° Fahr.; work the goods in this for twenty minutes; wring tightly out, in order not to lose much stuff; wash in a couple of waters, and dry.

If this color is passed through water made to taste sour by an acid, a very red orange, bordering on scarlet, is produced; but the hue is very fugitive.

Blues of different sorts are given at pages 647, 648.

21. *Logwood Blue.*—Dye first a light-blue with the vat, then lay in a hot decoction of two pounds sumach for several hours, and keep working for fifteen minutes through water, to which has been added one pint acetate of alumina—red liquor,—and one pint acetate of iron—iron liquor; wash from this in two tubfuls of hot water, then work twenty minutes in a decoction of two pounds logwood; lift, and raise with half a pint of red liquor; work ten minutes longer; wash, and dry.

22. *Fustic Green on Yarn.*—Dye a vat blue, wash and wring, and then pass through the acetate of alumina at 6° Twaddle; wash through a tub of hot water, and then work for twenty minutes in a decoction of four pounds fustic; lift and raise with two ounces alum in solution, work fifteen minutes, wash, and dry.

23. *Bark Green on Cloth.*—The goods after being cleaned, not bleached, are wrought for ten minutes in red liquor at 7° Twaddle, wrung out, and passed through a tub of hot water, and then wrought for half an hour in a decoction of three pounds bark, lifted and raised with half a pint red liquor, and wrought ten minutes longer, then lifted and drained. Into a tub of cold water add five gallons of chemic—neutralized sulphate of indigo—page 624; work the yellow in this for twenty minutes, wring out, and dry. Of course any depth of shade may be made in this way by varying the quantity of stuff used.

24. *Fustic Green on Cloth.*—Work the goods in acetate alumina at 6° Twaddle, and dry in a stove or hot chamber; then wet out in hot water, and work for twenty minutes through a decoction of three pounds fustic; lift, and raise with two ounces alum in solution; work fifteen minutes; wring out, and then work in the chemic prepared as in page 624; wring out, and dry.

25. *Green with Prussian Blue.*—Dye a good prussian blue, same way as sky—page 647—according to the depth of green required; and then work ten minutes in acetate of alumina at 6° Twaddle; wash in a tubful of warm water, and work for half an hour in a decoction of three pounds fustic; lift, and raise with two ounces of alum in solution; work ten minutes longer; wash, and dry.

Bark may be substituted for fustic in this green. If so, the bark should not be wrought very warm; and thus a finer tint is obtainable.

26. *Sage Green.*—Dye a prussian blue, same as sky—page 647—and work ten minutes in a solution of two pounds alum; wring out, and work fifteen minutes in a decoction of one pound fustic; lift, and add a pint of the alum solution formerly used; work ten minutes, and then wash and dry.

27. *Olive or Bottle Green.*—Dye a good shade of prussian blue—page 647—then mordant by working ten minutes in acetate of alumina at 7° Twaddle; wring out, and wash in hot water; work for half an hour in a decoction of three pounds of fustic and one pound of sumach; then add half a pint iron liquor,

and work fifteen minutes; then wash in one tub water having two ounces alum dissolved in it, and dry.

28. *Olive or Bottle Green—Another method.*—Work the goods in red liquor at 7° Twaddle, wash in warm water, and work half an hour in a decoction of three pounds bark and one pound sumach; lift, and add half a pint iron liquor, work other fifteen minutes; wring out, and then work fifteen minutes in the chemic—page 624; wring out of this, and dry.

29. *Olive Green.*—Dye a prussian blue—page 647—then work for ten minutes in red liquor at 6° Twaddle; wash in hot water, and work in a decoction of three pounds bark and one pound logwood; lift, and raise with half a pint of red liquor, and work ten minutes; wash from this, and dry.

A great variety of shades of green may be obtained by varying the proportions of bark and logwood. Fustic may also be used instead of bark.

If the goods be yarn, a light vat blue may be dyed instead of the prussian blue, and proceeded with afterwards in the same manner as above.

Other shades and qualities of green are given at page 644.

30. *Puce or Lilac.*—Work for an hour in red spirits, made down to 2° Twaddle; wring out, and wash, then work half an hour in a decoction of three pounds of logwood at working temperature, about 140° Fahr.; lift up, and add one gill red spirits, work for twenty minutes; wash from this, and dry. Half a pint of red liquor, or two ounces alum, may be added to the logwood as raising, instead of red spirits.

31. *Another method.*—Work the goods for fifteen minutes in red liquor at 7° Twaddle; wring out, and wash in one tub warm water, then work half an hour in a decoction of two pounds of logwood at working heat; lift, and raise with half a pint red liquor, or two ounces alum; work ten minutes in this, and wash in a tub of lukewarm water; wring out, and dry.

32. *Light-Purple or Adelaide.*—The goods are laid in a decoction of two pounds sumach, wrung out, and wrought half an hour through the spirit plumb—page 654; wring out, and wash in clean cold water till no taste of acid is felt on the goods, and dry.

When working with the spirit plumb, it is best to take the plumb liquor into a tub or separate vessel, and work the goods in this, returning the liquor afterwards to the plumb tub.

33. *Another method.*—The goods are laid in two pounds sumach, wrung out, and wrought for twenty minutes in red spirits at 2° Twaddle; wash well from this, then work in the spirit plumb in the same manner as last; wash out till no taste of acid is on the goods, and dry.

34. *Purple.*—Steep in two pounds of sumach till cool; work in red spirits at 2° Twaddle for an hour, and wash in cold water; then work for half an hour in a decoction of three pounds of logwood at working heat; then lift, and add one gill of red spirits, and work for ten minutes more; wash in cold water, and dry.

A variety of purple shades may be dyed by this process, by slightly varying the proportions of the stuffs. If a browner tint is required, give a little more sumach; if a bluer tint, less sumach, and increase the logwood, and raise with half a pint red liquor, or two ounces alum, instead of red spirits.

35. *Lavender or Peach.*—Work the goods for twenty minutes through the spirit plumb, wring out, and wash in clean cold water till no taste of acid is perceived, and dry.

36. *Logwood Lilac or Puce.*—Dye the goods a good shade of prussian blue—page 647—then work for fifteen minutes in a decoction of one pound of logwood at working temperature; lift up, and add four ounces alum; work ten minutes, and then wash in cold water, and dry.

37. *Another method.*—Dye a sky-blue—page 647—then, in a tub of warm water, add one gallon alum plumb—page 642—and work in this fifteen minutes; wring out, and dry.

38. *Safflower Lavender.*—Dye the goods a sky-blue—page 647—then dye a safflower pink on the top of the blue, with one pound safflower; but in dyeing the pink, the sulphuric acid must be added to the safflower liquor previous to the blue being entered into it, otherwise the alkali of the safflower will destroy the blue.

One need hardly add, that different depths of color, and different hues, will be obtained by varying the shade of blue and the quantity of safflower. Deep blue and little safflower give a lilac, or puce; while a light-blue, with four pounds of safflower, will give a peach color.

39. *Safflower Lavender—Another method.*—Dye a pink with two pounds of safflower—page 626—then proceed and dye a sky-blue over this—page 647—and finish exactly as described for sky-blue.

Of course the remarks made on last receipt, in reference to different shades, apply equally to this method; but more safflower is required by this method than the other.

40. *Common Drab.*—Work the goods for fifteen minutes in a decoction of half a pound sumach; lift, and add one ounce copperas in solution, and work for fifteen minutes; wash out in a tub of cold water, then work for fifteen minutes in a decoction of four ounces fustic, two ounces limawood, and one ounce logwood; lift, and raise with one ounce alum in solution; work ten minutes longer, wring out, and dry.

A great variety of shades can be produced by this means, varying the proportion of the limawood, fustic, and logwood; and different depths, by varying the quantities of sumach and copperas.

41. *Olive Drab.*—Work fifteen minutes in half a pound sumach, then add one ounce copperas, and work in this for fifteen minutes; wash in one tub water, and work in half a pound fustic for twenty minutes, and raise with one ounce alum; work ten minutes, and dry out.

42. *Drab.*—To a tub of hot water add one pint of annotta—page 656—which gives a light salmon color, then proceed with this exactly as last for olive drab; or, by varying the quantities in last operations, a great variety of drabs may be dyed.

43. *Stone Color.*—Work the goods twenty minutes in a decoction of one pound sumach; lift, and add one ounce copperas in solution; work fifteen minutes, and

wash in one tub cold water; then work ten minutes in warm water, to which half a pint alum plumb—page 642—has been added; wring, and dry.

This gives a reddish tint; but if this tint be not required, the alum plumb may be dispensed with, using half an ounce alum in the water.

44. *Catechu Stone Drab.*—Work the goods for fifteen minutes in two pints catechu—page 656—in hot water; lift, and add two ounces copperas in solution; work for fifteen minutes, and wash in one tub of water. Into another tub of warm water, add a decoction of two ounces logwood; work the goods in this for ten minutes; lift, and raise with half an ounce alum; work ten minutes longer, wring out, and dry.

45. *Catechu Drab.*—Work the goods for fifteen minutes in hot water, to which has been added one pint catechu—page 656—then lift, and add one ounce copperas; work ten minutes, and wash out and dry.

A variety of tints may be obtained by *topping* with a little different woods.

PREPARING AND DYEING OF SILK.—Silk is also banded in the same manner as cotton, using no particular number of hanks, but in quantities convenient for making up into skeins when finished. After banding, it is carefully tied up and put into fine canvas bags, and seethed in these in a strong solution of soap for three or four hours, until all the gum is boiled off. If the silk be yellow gum, it is put upon sticks like the cotton, and wrought in a solution of soft soap, at a temperature just approaching the point of ebullition, for about one hour, when it is tied up as the white gum silk, and put into bags and boiled till all the gum is removed; when boiled, it is washed from the soap, and *sticked* for dyeing, putting six or eight heads of silk on each stick. This is all that new silk requires before dyeing, but a great portion of the dyeing required by the amateur is re-dyeing, such as ribbons, handkerchiefs, dresses, shawls, *et cetera.* The first operation with goods to be re-dyed is steeping in a strong saponaceous solution at nearly 212° for a few hours, in order to remove stains of oil or grease; they are afterwards washed in water, and if the color remaining upon them after this operation be light and equal, and the color wanted be dark, then no more is required; but if unequal, they should be put into a sour—page 657—for fifteen minutes, then washed out, and proceeded with for the tint required.

The quantities of dyestuffs given in the receipts that follow, are for dyeing five pounds weight of silk. In cases where the silk is very hard spun, as in some ribbons and dresses, a little more dyestuff may be used than the quantities given, and also a little more time. Some kinds of goods will be bulkier than others of the same weight; in such cases, less or more water may be used accordingly. The quantity of water must always be sufficient to allow the goods to be quite loose when immersed under the surface.

When goods are washed from the dye, it is always in cold water, except otherwise mentioned in the prescription.

1. *Black.*—Work for an hour in a solution of eight ounces of copperas, and wash well out in cold water; then work an hour in a decoction of four pounds of logwood, adding to it half a pint of urine; lift out, and add to the logwood liquor two ounces copperas in solution; work fifteen minutes, wash, and dry.

This will give a good black, not very deep. If a deep black is required, add to the copperas solution two ounces, by measure, nitrate of iron; indeed, for re-dyes, it will be better to add this at all times. If a blue shade is desired, instead of adding urine, dissolve a little white soap in the logwood liquor, and add no copperas.

2. *Full Deep Black.*—Work an hour in one pound copperas and two ounces nitrate of iron, wash and work for an hour in a decoction of five pounds logwood and one pound fustic; lift, and add two ounces copperas, work ten minutes; wash, and finish.

If the color is not deep enough, add a little more logwood before raising with the copperas.

3. *French Black.*—Work an hour in one pound copperas and four ounces alum; wash well, and then work an hour in a decoction of four pounds logwood, in which a little white soap has been added; wash out, and finish.

4. *Blue Black by Prussiate.*—Dye a deep prussian blue as described—page 648—and work from the prussiate for half an hour in eight ounces copperas; wash well from this in cold water, and then work for half an hour in a decoction of two pounds logwood, using neither urine nor soap in it; lift, and add a little of the copperas solution with which the goods were mordanted; work other ten minutes, then wash and dry.

5. *Deep Hat Black.*—Work the silk fifteen minutes in a decoction of two pounds fustic and one pound bark; lift, and add in solution six ounces acetate of copper and six ounces copperas; work other fifteen minutes, and then sink the whole under the surface, and let it steep for several hours, say overnight; lift and wash from this, then make a decoction of five pounds logwood; dissolve in it as much white soap as will make a lather, and work in this for an hour; wash out, and dry.

6. *Brown.*—Dye an orange with annotta—see *Orange*, page 660; then work for fifteen minutes in a solution of eight ounces copperas; wash from this in two waters, and then work half an hour in a decoction of three pounds fustic, eight ounces logwood, and one pint archil liquor; lift, and add half a pint alum solution; work ten minutes, wash and dry.

One pound of brazil or peachwood may be substituted for the archil liquor, with nearly the same results. A variety of this shade of brown may be dyed by varying the quantity of each stuff.

7. *Brown.*—Dye an orange by annotta—see *Orange;* page 660; and then work for twenty minutes in a decoction of three pounds fustic, eight ounces sumach, eight ounces peachwood; lift up, and add three ounces of copperas in solution; work other fifteen minutes, wash out in two waters, using half a pint of alum solution in the last water.

If the particular tint required is not obtained by the above proportions, it may be given in the water with the alum, using it a little warm. If yellowness is required, add fustic. If redness is wanted, add peachwood. If depth or blueness, add logwood.

A great many particular hues of brown may be dyed by this method; as, for instance, by using only fustic and sumach in the second operation, a California brown is obtained, *et cetera*, as just referred to, so that any intelligent person will easily regulate his colors and tints.

8. *Red Browns.*—Dye a deep orange by annotta—see *Orange*, page 660; then work for fifteen minutes through the spirit plumb liquor—page 654—wash well, and dry.

Particular tints may be given by adding either logwood, peachwood, or fustic in the last washings, as described in last receipt.

9. *Another method.*—Steep the silk in an alum solution of eight ounces to the gallon for an hour, and wash out in warm water; then work half an hour in a decoction of one and a half pound fustic, one and a half pound peachwood, eight ounces logwood; lift, and add one pint of the alum solution, work for ten minutes; wash and dry.

10. *Chocolate Brown.*—Steep the silk for an hour in alum, one pound to the gallon of water; wash once in warm water, and then work for half an hour in a decoction of three pounds peachwood and one pound logwood; lift, and add one pint of the alum solution; work in this for fifteen minutes; wash out, and dry.

Deeper shades of chocolate are obtained by using a smaller quantity of peachwood and more logwood, in equal proportions. A little fustic, say four ounces, may be added, which will give a still deeper hue if required.

11. *Bronze Brown.*—Work for half an hour in a decoction of eight ounces fustic, to which four ounces, by measure, of archil liquor has been added; then lift, and add two ounces of the solution of copperas; work fifteen minutes, wash in cold water, and finish.

12. *Pink.*—Prepare the safflower as described—page 625; then take a quantity of solution equal to one pound of safflower originally used; add to this solution one ounce, by measure, of sulphuric acid; enter the silk, and work for half an hour; then wash in a vessel with warm water in which about one ounce cream tartar has been dissolved; wring out, and finish. Lighter or darker shades may be dyed by using less or more safflower; when more is used, a little more time will be required.

If safflower extract be used, which is simply the red coloring matter—carthamin—precipitated by an acid, add about a pint of the extract to warm water, with half a wine-glassful of sulphuric acid; stir well; work the goods in this, and proceed as above.

For other shades with safflower, as rose, crimson, *et cetera*, see page 626.

13. *Cochineal Crimson.*—To every gallon of water used, add about two ounces, by measure, bichloride of tin—page 653; allow any sediment to settle, and take the clear solution, and apply heat; when warm, work the goods in it for an hour or more.

Boil in a bag two pounds of cochineal, by suspending it on the surface of the water for half an hour; add this to the proper quantity of water for working the goods, the whole being at hand heat; wring the silk from the spirits, and work it in this cochineal solution for half an hour, when it is let steep for several hours, keeping well under the liquor; wash well out of this in cold water. If the shade is not blue enough, a little cochineal dissolved in ammonia may be added to the water; and after working in this for ten minutes, wring out, and dry.

14. *Common Red.*—Make a decoction of two pounds peachwood and one pound fustic, work the goods in this for fifteen minutes; lift up, and add four ounces, by measure, red spirits; work again fifteen minutes; wash in cold water, and finish.

A variety of tints may be dyed in this way by altering the proportions; and by adding a little logwood, clarets and such shades can be produced; but these common colors do not stand the air well.

15. *Cochineal Pink.*—This hue is dyed in the same manner as the crimson, only using much less cochineal; about half a pound will make a good color. Different shades of pink, rose, and crimson can be dyed by this method, by varying the quantities of stuff used.

16. *Cochineal Scarlet.*—Dye a deep orange by annotta—see *Orange*, page 660; and proceed in the same way as for crimson, passing through the spirits, and then cochineal, as stated above.

Different shades of common reds and crimsons may be dyed by mixing up the following:—Make a strong decoction of lima or brazil-wood by boiling, using at the rate of one pound wood to the gallon of water. When the boiling has ceased and the wood settled to the bottom, decant the clear and allow it to cool for twenty-four hours, then decant again from any sediment that may have collected, and to every gallon of liquor add half a pint plumb spirits, stir well, and let stand for several hours, when it is fit for use.

17. *Common Crimson.*—Into a copper or stoneware vessel put some of the above liquor, work the goods in it for half an hour; then wash out in cold water until no taste of spirits is perceptible in the cloth; wring, and dry.

18. *Common Scarlet.*—Dye the goods an orange by annotta—see *Orange*, page 660; and then work in the peachwood preparation in the same way as dyeing common crimson; wash out, and dry.

19. *Rubys, Maroons, et cetera.*—Take one pound of cudbear and boil for fifteen minutes in a bag; work the silk in this solution for half an hour. If the shade required be of a bluish tint, lift, and add three ounces, by measure, liquid ammonia; work ten minutes, and wring and dry.

If the shade required be of a red hue, lift, and add two ounces, measure, red spirits; work ten minutes; wash out, and dry.

If a brown hue is wanted, use along with the cudbear a decoction of four ounces fustic; work in this, and raise with two ounces red spirits, as above.

If a deep violet hue is desired, employ along with the cudbear a decoction of four ounces logwood; work in it, and raise with two ounces red spirits, as above.

20. *Sky-Blue.*—To one pint of sulphate of indigo add two or three gallons boiling water; then put into this a piece of woollen cloth, such as an old blanket; after steeping for a day, take it out and wash in cold water.

If the sky-blue required be very light, make up a vessel with warm water, about 98°, steep the blue cloth in this for a few minutes, and wring out, when as much blue will be dissolved off as will dye the silk; add an ounce of alum in solution, and work the silk in this for twenty minutes; wring out, and dry.

If the blue required be deep, then, to the warm water in which the blanket is put, add one ounce of pearl-ash, and proceed as detailed; but before adding the silk, a few drops of sulphuric acid may be poured in with the alum to neutralize the alkali.

If indigo extract be used, then the blanket or woollen cloth is not required, but to the requisite quantity of water add half an ounce of extract, with one ounce of alum in solution, and work the silk as stated; less or more of the extract is used according to the depth of shade required.

For prussian blues on silk, see page 648.

21. *Lavender.*—Into as much water as will work the goods in easily, put one pint of spirit plumb liquor; stir well, and work the goods in this for twenty minutes, then wash out in cold water, and dry.

Darker or lighter shades can be dyed by using less or more of the plumb liquor.

If a blue tint of lavender is required, add to the plumb liquor solution, before putting in the goods, two or three drops of sulphate of indigo, or extract, and proceed as stated.

22. *Lavender—Another method.*—Into a vessel with warm water as hot as the hand can bear, dissolve a little white soap, enough to raise a lather; then add one gill archil liquor, and work the goods in this for fifteen minutes; wring out, and dry.

Boil one ounce of cudbear, and add the solution to the soap and water, instead of archil, which will give a lavender having a redder tint than that with the archil. If a still redder shade of lavender be required, the soap may be dispensed with.

23. *Wine Color, Violet, Lilac, et cetera.*—Into a copper pan or stoneware vessel, put as much of the plumb liquor as will work the goods in; then work in this for twenty minutes; wash out in two or three waters, or until the goods have no taste of the plumb, then dry.

If a rich blue tint is required, add to the plumb one ounce, by measure, sulphate of indigo, or extract. If a red tint is desired, dye the cloth first a lavender by cudbear, without soap; then work through the plumb liquor, without indigo.

The plumb liquor used for this color is not thrown away; it is either put back into the stock tub, or into another vessel kept for that purpose, when it may be used over again. If indigo has been taken, it must not be put back into the stock plumb, or it will give the whole a blue shade—all such mixture should be kept separate.

24. *French and Pearl White.*—Into hot water dissolve a quantity of white soap, as much as makes a lather, and then add about half an ounce, by measure, archil; work the goods in this for ten minutes, and finish out the soap.

A little cudbear may be used instead of archil, less or more according to the shade required.

25. *Another method.*—Into a vessel of cold water, add about one ounce, by measure, of plumb liquor; work the goods for ten minutes; wash out, and dry.

For these shades the goods should be perfectly white previous to dyeing.

26. *Weld, Yellow.*—Work the silk for an hour in a solution of alum, about one pound to the gallon, wring out, and wash in a vessel with warm water. Boil two pounds weld, strain the liquor, and work the alumed silk in this for half an hour, then add one pint of the alum solution to the weld bath, and return the silk; work for ten minutes longer, and wring out and dry.

This gives a rich lemon-yellow; by adding more weld, deeper shades are produced; or by using a little annotta, amber and straw tints are obtained.

For other shades of yellow on silk, see page 624.

27. *Gold and Straw.*—Into warm water with white soap, add two pints annotta liquor; work in this fifteen minutes; wash out, and then work twenty minutes through a decoction of eight ounces bark; lift, and add one ounce, by measure, red spirits; work other ten minutes, wash out, and finish.

Different tints of these colors may be dyed by varying the quantity of annotta bottom and bark.

28. *Salmon, Flesh, Nankeen, Buff, et cetera.*—Make a solution of white soap in warm water, and to this add one pint of annotta liquor; work twenty minutes, wring out, and finish. If the shade is not deep enough, add a little more annotta.

If a red tint is required, such as salmon or flesh color, the goods are washed out of the soap, and finished in cold water, in which two ounces of alum are dissolved.

29. *Orange.*—The silk is wrought for fifteen minutes in a strong solution of annotta—page 656—made warm; then wash in warm water, and dry.

The annotta made up for silk should be with soft soap, instead of potassa or soda, or only a very little of these alkalies should be added.

30. *Yellow Drab.*—Into a vessel with warm water add one pint annotta liquor; work in this for fifteen minutes, and wash; then work another quarter of an hour into a decoction of half a pound sumach and one pound fustic; lift up, and add four ounces copperas in solution and one ounce alum; work ten minutes, and wash in cold water, and dry.

A diversity of shades of drab may be dyed in this way, by varying the proportions of the stuff, and adding with the fustic small quantities of log and peachwood.

31. *Drab.*—Work the goods for fifteen minutes in a decoction of eight ounces sumach, and the same of fustic; lift, and add four ounces copperas; work twenty minutes, and wash out in cold water. In another vessel with warm water add half a pint archil liquor; work fifteen minutes in this, and dry out.

If a greenish tint be required, add a decoction of four ounces fustic to the archil, and half an ounce, by measure, of chemic—page 624. If a purple tint is sought, add, instead of the chemic, one ounce of alum in solution.

A great variety of tints may be produced by a slight alteration in some of these ingredients.

32. *Slate or Stone Color.*—Into a decoction of one pound sumach, four ounces fustic, and four ounces logwood, work the silk for half an hour; lift, and add a solution of four ounces copperas; work other thirty minutes, wash in cold water, and finish.

A variety of tints can be produced by this method, by taking different proportions of the stuffs.

33. *Common Green.*—Steep for an hour in an alum solution of one pound to the gallon; wash in warm water, and work for thirty minutes in a decoction of six pounds fustic; then add two ounces, by measure, indigo extract; work other thirty minutes; wash, and finish.

Should the shade be too yellow, as the extract often varies in quality, add more extract to the fustic before finishing.

Deeper and lighter shades are dyed by this method, by using more or less of each stuff.

34. *Another method.*—Work for forty minutes in a decoction of four pounds fustic; lift, and add one pound alum in solution, and two ounces, by measure, of indigo extract; work for half an hour in this; wash out in cold water, having in it half a pint of alum solution, and finish.

35. *Pea Green.*—Steep the silk for an hour in an alum solution of eight ounces to the gallon of water, and then wash out in warm water; boil four pounds ebony wood chips for an hour; take the clear, and work the silk in it for thirty minutes; lift, and add half an ounce indigo extract; work ten minutes; wash in cold water, having half a pint of alum solution in it. and dry.

Care has to be taken in adding the extract, lest the quantity given be too much for the shade required; it may be better to add less, and if found not enough, lift, and add more.

36. *Bottle Green.*—Dissolve two pounds alum and one pound copperas; work the silk in this for an hour, and wash out in warm water; then work for half an hour in a decoction of six pounds fustic; lift, and add two ounces, by measure, indigo extract; work twenty minutes, wash out, and finish.

37. *Another method.*—Proceed exactly as described for common green; but add one pound of logwood to the six pounds of fustic, and operate in every way the same.

If a deeper shade be required, a little more logwood may be added.

38. *Olive.*—Work the silk for half an hour in a solution of one pound of copperas and four ounces of alum; wash out in hot water, and then work half an hour in a decoction of two pounds fustic and four ounces of logwood; lift, and add half a pint alum solution or two ounces dissolved; work ten minutes in this; wash, and dry.

If the shade looked for have more of a green hue than pattern, add a little chemic to the last water, and work ten minutes, and dry out.

39. *Light Olive.*—Dye a light prussian blue—see *Sky-blue*—then work for twenty minutes in a decoction of two pounds fustic and half a pint archil liquor; lift, and raise with half a pint alum solution, or one ounce dissolved; work ten minutes, and finish.

PREPARATION AND DYEING OF WOOLLEN STUFFS.—Woollen is also banded with twine into spindles, previous to being put under operations for scouring or dyeing. It is then steeped overnight in soap lie, or old alkaline solutions, and then scoured through clean soap to remove all oil or grease that may be upon the wool; or, what is more common, a scouring liquor is prepared with one pound of soft soap and one pound of common soda, or half a pound of soda ash, in ten gallons water, and scoured through this.

This is the only preparation that new wool is subjected to previous to dyeing.

For re-dyes every care should be taken to remove all grease or oil first, or no good dye can follow. This is done by steeping and scouring in soap and soda. If the remaining color be unequal or dark, the goods are steeped or wrought for a little in a sour made up of bisulphate of potassa—dissolving two ounces to the gallon of water.

Woollen is always dyed hot; the liquid usually being near to the boiling point, which necessitates its being dyed in a boiler. Iron vessels are not used for this purpose. Copper, and copper with tin, is most generally used. The dyestuffs, such as ground wood, are generally put into the boiler and the goods wrought with it, but it is cleaner to make a decoction and use the clear liquor.

All washings are made in cold water, except warm be specified in the directions.

In the following receipts, the quantity of goods referred to is ten pounds, whether in cloth or yarn:—

1. *Black.*—Work for twenty minutes in a bath with eight ounces camwood; lift, and add eight ounces copperas; work other twenty minutes; then withdraw the fire from the boiler, and submerge the goods in the liquor overnight; then wash out. Into another bath, with five pounds logwood and one pint chamber lie, work for an hour; lift, and add four ounces copperas; work in this half an hour longer; wash, and dry.

2. *Brown.*—Work for an hour in a bath made up with two pounds of fustic, two pounds of madder, one pound of peachwood, four ounces of logwood; then lift, and add to the bath a solution of two ounces of copperas, and work half an hour in this; wash out, and dry.

3. *Brown.*—Work for an hour in a bath of four pounds of fustic, two pounds of camwood, half a pound of logwood; lift, and add to the bath four ounces of copperas; work half an hour in this; wash, and dry.

For other methods of dyeing black and brown, see page 645.

4. *Crimson.*—Work in a bath for one hour with one pound cochineal paste, six ounces dry cochineal, one pound of tartar, one pint of protochloride of tin; wash out this, and dry.

5. *Scarlet.*—Work for an hour in a bath with one pound of tartar, two ounces of dry cochineal, eight ounces of sumach, eight ounces of fustic; wash out, and dry.

6. *Red.*—Work half an hour in a bath with one ounce of bichromate of potassa, one ounce of alum; wash out this through cold water; then work for half an hour in another bath with three pounds of peach or limawood; lift, and add one ounce of alum; work in this for twenty minutes; wash, and dry.

7. *Claret Red.*—Work for an hour in five ounces of camwood; lift out, and expose until the goods are well drained and cold; in the interim, add to the bath with

the camwood, four ounces of copperas, two ounces of alum, eight ounces of logwood; work the goods in this for half an hour; wash, and dry.

8. *Lac Scarlet.*—Work for half an hour in a bath with one pound of tartar, eight ounces of sumach, two pounds of lac; lift, and add about a gill of bichloride of tin, and work in this for half an hour; lift, wash, and dry.

9. *Pink.*—Work one hour in a bath with one pound of tartar, eight ounces of alum, one pound of cochineal paste, one gill measure of red spirits; wash out in cold water, and dry.

10. *Yellow.*—Work for twenty minutes in a bath with eight ounces of tartar, eight ounces of alum; lift, and add to the bath two pounds of bark, eight ounces of sumach, eight ounces of fustic, one pint of red spirits; work in this for forty minutes; wash out, and dry.

11. *Orange.*—Work for forty minutes in a bath with two pounds of sumach, three ounces of cochineal dry, one pound of fustic, eight ounces of tartar, one pint of red spirits; wash out this, and dry.

12. *Sky-Blue.*—Work in a bath for half an hour with eight ounces of argol, one pound of alum, one gill of indigo extract; wash out this, and dry.

Different depths of shade may be made by varying the quantities of indigo extract.

For other shades of blue, see page 648.

13. *Pigeon Blue.*—Work in a bath for forty minutes with two ounces of chrome, four ounces of alum, one ounce of tartar; wash from this in cold water, and then work for half an hour in another bath with three pounds of logwood; lift, and add one ounce of verdigris; work for fifteen minutes, and wash, and dry.

14. *Apple Green.*—Work for half an hour in a bath with one ounce of chrome, one ounce of alum; wash through cold water, and then work for half an hour in a second bath with two pounds of fustic and eight ounces of logwood; wash, and dry.

A variety of this shade can be obtained by diversifying the proportions and quantities.

15. *Green.*—Work for fifteen minutes in a bath with five pounds of fustic, two ounces of argol, five ounces of alum; lift, and add half a gill of indigo extract; and then work for half an hour, and dry.

If the green seem too yellow, a little more extract of indigo may be mixed with the others.

16. *Fast Green.*—This is first dyed blue in the indigo or woad vat, according to the depth of green required, and then work for an hour in a bath with four pounds of fustic, two pounds of alum, and dry out.

By dyeing the vat blue lighter than is required for the green, and adding to the bath with the fustic a little logwood, will give the required depth and a good shade; but the color is not so fast.

See page 648 for other shades of green.

17. *Olive.*—Work for an hour in a bath with ten ounces of fustic, eight ounces of logwood, four ounces of madder, two ounces of peachwood; lift, and add to the same bath four ounces of copperas in solution, and work for half an hour, and dry—see page 648.

18. *Wine Color.*—Work the goods for an hour in a bath, with four pounds of cudbear, and dry.

If a darker shade be required, give more cudbear; if the tint be desired bluer, add, after half an hour's working, one gill of ammonia: if a redder tint is wanted, add a wine-glassful of hydrochloric acid.

If the acid be added, the goods should be washed before drying.

19. *Light Violet.*—Work for an hour in a bath, with four ounces of cudbear, four of logwood, two of barwood or camwood, two of peachwood; lift, and add two ounces of alum in solution, and work half an hour, and dry.

20. *Puce.*—Work in a bath for one hour, with ten ounces of logwood, one ounce of camwood, eight pounds of cudbear; lift, and add two ounces of copperas in solution; work half an hour, and dry.

21. *Brown Drab.*—To the dye bath, add two ounces ground madder, one ounce peachwood, two ounces of logwood, six of fustic, and work in this for thirty minutes; lift up, and add three ounces of copperas in solution; mix well, and work the goods in this for other thirty minutes; wash, and dry.

This shade can be greatly varied, either by altering the quantity of stuffs, or the proportions of any of them; if a redder tint be required, add more peachwood or madder—the latter gives the drab hue; if more yellow, add fustic; if more slate or black, add logwood, and *vice versâ.*

22. *Stone Drab.*—Into the proper proportion of water add one ounce of peach or limawood, two ounces of logwood, half an ounce of fustic; work in this for twenty minutes, and then lift out, and add to the dye bath one ounce of sulphate of iron in solution; stir well, and work in this for another half hour; lift out, and expose to the air for a short time; wash, and dry.

A diversity of shades may be dyed, by altering the quantities and the proportions of the dyestuffs.

23. *Slate.*—Work for half an hour in a bath, with eight ounces of logwood, one ounce of fustic; lift, and add to the bath a solution of one ounce of alum, half an ounce of copperas; work in this half an hour; wash, and dry.

Different tints of this color can be obtained by varying the stuff; if more blue be required, use less alum and more copperas; if more to the purple, less fustic and more alum; and so by a very little practice any particular hue can be dyed.

For dyeing woollen blue in vats—see article VATS—which serve both for woollen and silk; the operation is simply dipping or working in the vat, and then exposing to the air.

MIXED FABRICS DYED TWO COLORS.—Mixed fabrics of cotton and woollen, as coburgs and damasks, are very common; these are either dyed all of one hue, or the cotton and woollen are dyed of different colors. This last is seldom done, except with new goods, or in cases where very light-colored goods are wanted a dark shade, in which case a light and dark tint may be communicated. The process for doing this is very simple. As the process used for woollen will seldom produce the same color on cotton, the two have to be dyed separately. For most colors it is necessary to dye the woollen first, and then the cotton; in a few the cotton is dyed first. In most cases, the processes given will serve the purpose; as, for instance, *Green and Pink.*—The woollen is first dyed a green, by any of the processes—No. 15 or 16, page 666—and then the cotton is dyed pink, by the process, page 625.

Green and Crimson.—Dye the woollen by working for an hour in two pounds of tartar, four pounds of alum, six pounds of fustic, and then add half a pint of indigo extract, wash out, and lay overnight in six pounds of sumach; work half an hour in red spirits, made to 2° Twaddle; wash and work for an hour in five pounds of peachwood at hand heat; raise with alum; wash, and finish.

Blue and Orange.—First dye the cotton a blue by the blue vat, wash, and then dye the woollen by working one hour in two pounds of tartar, eight ounces of cochineal, two pounds of fustic, and two pints of bichloride of tin; wash from this, and dry.

In this way almost any two colors may be dyed upon cotton and woollen, although woven together, by proceeding as the receipt for the tint required on each sort of fibre; and except as in last recipe, where cotton is dyed by the blue vat, and consequently fast, the woollen is always to be dyed first. The same rule is applicable to silk and woollen. The two have to be dyed separately, although in many cases the silk becomes more imbued during the dyeing of the woollen than the cotton is.

A mixture of silk and cotton, when required of two shades, has also to be done in the same manner; but it is much more difficult, and cannot be done with all kinds of colors; it is a process, however, seldom resorted to. But the intelligent dyer will be able to dye any two tints by following the rules and receipts given.

MIXED FABRICS DYED ONE COLOR.—Should the mixed fabrics be required all of one color, the same double process has often to be adopted, especially when the fabrics are cotton and woollen; as, for instance,

Black on Cotton and Woollen.—The woollen is dyed first, as in page 665; and then, to dye the cotton, the goods are laid in sumach, and dyed as in page 659, and so on for any color of these mixed fabrics.

Brown on Cotton and Woollen by one Process.—Work the goods for two hours in catechu, same as page 656; then work for an hour at boiling heat with eight ounces of chrome and two ounces of tartar; lift out, and work an hour in two pounds of fustic and eight ounces of cudbear; wash, and dry. Should a deeper shade be required, or a tint more of the chocolate hue, add with the cudbear four ounces of logwood.

Black on Silk and Woollen by one Process.—Work an hour in a solution of eight ounces of tartar and eight ounces of copperas, and wash out; work for fifteen minutes in a decoction of four pounds of logwood; lift, and add one ounce bichromate of potassa; work half an hour, and dry.

Black on Cotton, Silk, and Woollen, by one Process.—Steep for six hours in two pounds of sumach, then work for an hour in a solution of six ounces of tartar, six ounces of sulphate of copper, and six ounces of copperas; wash from this, and work half an hour in a decoction of four pounds of logwood; lift, and raise with one ounce of copperas; work ten minutes; wash, and dry.

Should a very deep black be required, add one pound of bark with the logwood; all else the same.

Drabs on Cotton, Silk, and Woollen, by one Process.—Work half an hour in eight ounces of sulphate of iron, and four ounces of tartar; lift, and drain; then work for half an hour in four ounces of logwood and one ounce of bichromate of potassa; wash out, and dry.

By varying the quantity of these stuffs, or by using a little fustic or peachwood in the last bath, a great variety of shades of drab, slates, or fawns may be produced, the different fibres being equally dyed.

These few receipts for dyeing mixed fabrics will show the care required in such operations; nevertheless, by a little practice they all become simple, and new methods and modifications are continually being introduced.

An interesting and ingenious application of sulphate of indigo, prepared in a certain form, has been proposed for dyeing particular shades of blue or lilac on woollen and silk, by M. E. HAEFFELY; the paper is nearly given as read to the Manchester Philosophical Society:—

This chemist commences his essay with drawing the attention of the society to a new fact, demonstrated in the successful application on worsted and silk of the red sulphate of indigo.

This chemical compound is produced by the action of sulphuric acid upon indigo, and by throwing the mixture thus obtained into a large quantity of water a few minutes after the contact. By this means a red-colored precipitate is formed, which, when well and thoroughly washed on a filter, represents the red compound in question, a very different production from the blue sulphate of indigo in its composition, properties, and as regards the shades produced by it.

He has been able to produce with this red sulphate of indigo, shades superior in all respects to those obtained by the employment of the indigo extract, imitating the prussian blue, and likewise purple shades bearing an imitation of those produced by the use of logwood and cudbear, which tints, he observes, cannot be produced from the commercial indigo carmin. Owing to this he was induced to communicate the results of the experiments he made in this matter, and at the same time exhibit for inspection some patterns, the effects of the putting into operation of both processes, so that the difference between the two may be fairly estimated. After a careful examination of these patterns, he felt assured every one would be inclined to give a preference to the blue and purple colors obtained by the use of the red sulphate introduced into commerce, and applied by dyers with success in some of the Yorkshire establishments.

He next entered into a few details respecting the chemical nature of these two sulphates. Upon an examination of the formulæ of the two chemical bodies referred to, it will be found that the ordinary indigo extract is, properly speaking, a hyposulphate of dehydrogenised indigo

$$= N\ C_{16}\ H_4\ O_2\ S_2\ O_5,$$

the formula of the indigotin being

$$N\ C_{16}\ H_5\ O_2,$$

whilst the red compound is a sulphate of indigotin—

$$N\ C_{16}\ H_5\ O_2,\ H\ O,\ S\ O_3.$$

Upon a comparison of these two formulæ, it will be remarked that, in the case of the indigo extract, the indigo and the sulphuric acid have undergone remarkable alterations: the indigo having lost a portion of its hydrogen, and the sulphuric acid a portion of its oxygen, —and these two elements, hydrogen and oxygen, having united to form water. But in the case of the red sulphate, the indigo and the sulphuric acid have entered into combination *without* undergoing any change.

As in the composition of the red sulphate, the tinctorial matter is, or appears, *unaltered*, he was induced to entertain the supposition that it might be beneficially used in dyeing for obtaining solid blues directly, an operation which might probably replace with advantage the process of obtaining blues from vats.

A circumstance which is in favor of the possibility of fixing this coloring matter on fabrics in a state of indigotin is, that some organic substances—such as sulphovinic acid, sulphoglyceric acid, and other sulphoacids —possess the property of being decomposed, and resolving themselves into their primitive constituents by a simple ebullition in water.

This red sulphate of indigo may be ranked in that type of organic bodies, where it figures under the name of *sulphopurpuric acid.* As it ought to partake of the properties of the series of compounds mentioned, it should necessarily, on its ebullition in water, decompose itself into *free indigo* on one side, and into *free* sulphuric acid on the other. Consequently, HAEFFELY presumed, that by immersing fabrics in the vessel where the process was going on, and at the moment of the separation of the coloring matter, he could fix this color upon the fabrics so introduced.

But the first experiment made did not turn out to be satisfactory. Cotton remained untouched by the color, whilst the worsted took off and successfully retained the tinctorial matter. Three consecutive trials were made on the occasion: the first in a neutral bath, the second in an acid bath, and the third in an alkaline one; but in all the three cases, so far as the cotton was concerned, there was no gratifying result. Hence it appears that the cotton has no affinity for this indigo. But silk and worsted may be effectually dyed in the way indicated, if the bath be only kept acid.

As already observed, some of these patterns imitate the prussian blue, and those washed in soap or alkaline water resemble the purple produced from logwood and cudbear, which shades could not, up to the present time, be produced by the employment of indigo alone.

A question which it will now be worth while particularly to inquire into is this—whether the indigo appears *on these fabrics* as indigotin, or as sulphopurpuric acid, or as a modification of this acid?

The opinion inclined to is, that it is a modification of indigotin, or of the acid coloring substance; for he found that this sulphopurpuric acid, in contrariety to the view generally entertained, is an intense red-colored compound *when dry*, and not a deep blue one.

Nevertheless, upon examining the patterns dyed with this *red compound*, it will be found that they *are blue on these fabrics*, and *not red;* and those patterns passed through alkali *are purple*, an effect which is not produced by indigotin.

This question has not been yet completely solved, and for the present this chemist only takes the liberty of calling attention to the new shades obtained by the employment, in the dyeing process, of this sulphopurpuric acid, namely, the blue, imitating prussian blue, and the indigo purple imitating the shades obtained by the use of logwood.—*Haeffely.*

TURKEY-RED.—The principal use of madder is to dye cotton cloth different shades of red; and by far the finest hue of all is that which is known in this country and on the continent by the name of Turkey or Adrianople red—one of the most durable colors known. Everything seems to prove that the method of dyeing this tint —the characteristic of which consists in previously impregnating the goods with an oily or fatty substance— was first discovered in India, where, as travellers affirm, the natives have been wont, from time immemorial, to steep the yarns which they intend to dye in liquids containing fatty matter—such as milk, for example. It was not, however, till after it had made its way into other parts of Asia, and become known in the countries of the Levant, undergoing at the same time important modifications, that this art was first introduced into France towards the middle of the last century. In 1747, MM. FERQUET, GOUDARD, and D'HARISTOY brought a party of Greek dyers into that country, and formed two establishments—one at Darnetal, near Rouen, and the other at Aubenas, in Languedoc. Nine months later, a person named FLACHAT, who had long resided in the Ottoman empire, brought over workmen, with whom he formed at St. Chamont, near Lyons, a third establishment for the dyeing of Adrianople-red—so called from the high celebrity then enjoyed by the productions of that city. But these foreigners could not long keep their art secret; they had soon numerous imitators; and, in 1765, the French government, convinced of the value and importance of this method of dyeing, made the processes known to the public. Many establishments were formed in various parts of the country; but it appears that the only successful ones for some years were those at Rouen. From these parts, the Turkey-red dye gradually made its way into Alsace, Switzerland, Great Britain, and different parts of Germany. At first, the cotton was only dyed in the yarn; and it was not till 1810 that the cloth itself was dyed directly of this color at the establishment of Messrs. KŒCHLIN, Mulhausen, and that of L. WEBER.

It is stated by the late Dr. THOMSON of Glasgow, and other authorities, that the first Turkey-red work in Great Britain was established in that city about seventy years ago by M. PAPILLON. It appears, however, from a paper on the Art of Dyeing, read before the Literary and Philosophical Society of Manchester, by Mr. THOS. HENRY, in 1786, and quoted by Mr. BAINES in his History of the Cotton Manufacture, that M. BORELLE, another Frenchman, introduced the art of dyeing Turkey-red at Manchester, probably some years previous to its introduction at Glasgow, and that he obtained a grant from Government for the disclosure of his plans, as M. PAPILLON afterwards did from the commissioners and trustees for manufactures in Scotland; but the method of the latter obtained the most decided success. It was in the year 1783, that Mr. DAVID DALE and Mr.

GEORGE MACINTOSH—father of the late Mr. CHARLES MACINTOSH, the inventor of the well-known waterproof fabrics—engaged PAPILLON, who was a dyer at Rouen, to settle in Glasgow, and he there founded and carried on for many years, in partnership with Mr. MACINTOSH, the celebrated Turkey-red business now conducted by the firm of Messrs. MONTEITH and Co. The period having expired in 1803, when the process was to be divulged, the commissioners and trustees above mentioned laid a complete account of it before the public. Since that period, Turkey-red dyeing has been conducted in Glasgow, and also in Lancashire, on a very extensive scale.

The following is the process given by Dr. THOMSON, as followed by the most skilful Turkey-red dyers in Glasgow:—

1. The cloth is steeped in a weak alkaline lie to remove the weaver's dressing. This is technically called the *rot steep.* From four to five pounds of caustic potassa are generally employed for every one hundred pounds of cloth. The temperature of the solution is from 100° to 120°. The cloth is kept in the steep for twenty-four hours, and then well washed.

2. From seven to ten pounds of carbonate of soda are dissolved in a sufficient quantity of water to keep the cloth—always supposed to be one hundred pounds—wet. In this solution the cloth is boiled for some time.

3. It is upon the third process that the beauty of the color depends more than on any other. Without it the dye cannot be produced on new cloth. But when old cotton cloth that has been frequently washed—a cotton shirt, for example—is to be dyed, this process may be omitted altogether.

A liquor is composed of the following ingredients:—

One gallon Gallipoli oil;

One gallon and a half of soft sheep's dung;

Four gallons of a solution of carbonate of soda, of the specific gravity 1·06;

One gallon of solution of pearl ashes, of the specific gravity 1·04.

These to be mixed up with a sufficient quantity of cold water, to make the whole mixture amount to twenty-two gallons. The specific gravity of this liquor should be from 1·020 to 1·025.

This menstruum has a milk-white appearance, and is in fact a kind of imperfect soap. It is put into a large wooden, open, cylindrical vessel, called the *liquor tub*, and is kept constantly in motion, to prevent subsidence, by wooden levers driven round in it by machinery. This liquor is conveyed by tin pipes to a kind of trough, in what is called the *padding machine*, where the cloth is thoroughly soaked in it. The longer the cloth is allowed to remain impregnated with this solution, the better does it take the dye. Fourteen days is the least period that this impregnation is allowed to remain.

The padding machine is similar in principle to that employed for starching, as described at page 317, and other forms of it will be described and delineated in connection with the *padding style* of calico-printing.

The sheep dung gives the cloth a green color, and is found materially to assist the bleaching process, to which it is afterwards subjected. It is found to increase the rapidity of the bleaching, especially when the cloth is exposed on the grass between the different operations

4. In favorable weather, the cloth impregnated with the imperfect soap of No. 3, is spread upon the grass to dry. But in rainy weather it is dried in the stove or *hot flue.* This method of exsiccating dyed and printed goods will likewise be fully described in connection with calico-printing.

5. The cloth thus exsiccated is a second time impregnated with the oleaginous liquid of No. 3. It is then dried again.

The impregnation and drying are repeated a third time.

6. The cloth is steeped in a weak solution of pearl ash, of a specific gravity from 1·0075 to 1·01, heated to the temperature of 120°. From this liquor it is wrung out, and again dried.

7. A mixture is made of the following substances:—

One gallon Gallipoli oil,

Three gallons soda lie, of specific gravity 1·04,

diluted with as much water as will make up the whole to twenty-two gallons. In this liquid the cloth is soaked as it was in that of No. 3.

The cloth thus impregnated is in fine weather dried on the grass, in rainy weather in the stove.

8. The process No. 7 is repeated thrice, and after each soaking the cloth is exposed for some hours on the grass, and finally dried in the stove.

9. The cloth is steeped in a mixed lie of pearl ash and soda, of the specific gravity 1·01 to 1·0125, heated to the temperature of 120°. It is allowed to drain for some hours, and then well washed; it is then dried in the stove. The object of this process is to remove any superfluous oil which might adhere to the cloth. Should any such oil be present, the succeeding process, the *galling*, could not be accomplished.

10. For the galling, eighteen pounds of Aleppo galls are to be boiled for four or five hours in twenty-five gallons of water, till the bulk is reduced to about twenty gallons. This liquid, after straining, is strong enough to impregnate one hundred pounds of cloth with the requisite quantity of nutgalls. Of late years, sumach from Sicily has been substituted for nutgalls; thirty-three pounds of the former being reckoned equivalent to eighteen pounds of the latter. Sometimes a mixture of nine pounds of nutgalls and sixteen pounds and a half of sumach is employed.

In this liquor, heated to 80° or 100°, the cloth is fully soaked. The sumach gives the cloth a yellow color, which serves to improve the madder-red, by rendering it more lively.

11. The next step is to fix the alumina on the cloth. This process is essential, because without it the madder dye would not remain, but would be washed off by water.

In this country alum is used by the manufacturers, but in many parts of the continent acetate of alumina is employed. To form the alum liquor of the Turkey-red dyers, to a solution of alum, of the specific gravity 1·04, as much pearl ash, soda, or chalk is added, as is sufficient to precipitate the alumina contained in the alum. Through this muddy liquor, which should have a temperature of from 100° to 120°, the cloth is passed, and steeped for twelve hours. The alumina is imbibed by the cloth, and combines with its fibres.

12. The cloth thus united with alumina is stove-dried, and then washed out of the alum liquor.

13. These essential preliminary steps having been taken, the cloth is ready to receive the red dye.

From one to three pounds of madder, reduced to the state of powder, are employed for every pound of cloth; the quantity depending upon the shade of color wanted. The cloth is entered into the boiler while the water is cold. It is made to boil in an hour, and the boiling continues for two hours. During the whole of this time the cloth is passed through the dyeing liquor by means of the winch.

For every twenty-five pounds of cloth dyed, one gallon of bullock's blood is added. This is the quantity of cloth dyed at once in a boiler. The addition of the blood is indispensable for obtaining a fine red color. Many attempts have been made unsuccessfully to leave it out. It seems probable that the coloring matter of blood is fixed on the cloth. Its scarlet tint would doubtless improve the color of madder-red.

14. *Madder-brown*, by this process, is fixed on the cloth as well as madder-purple or madder-red. This gives the cloth a brownish-red and rather disagreeable color. But the brown tinge not being nearly so fixed as the red, it is got rid of altogether by the next process, which is known by the name of the *clearing* process. The cloth is boiled for twelve or fourteen hours in a mixture of five pounds soda, eight pounds soap, and from sixteen to eighteen gallons of the residual liquid of No. 9, with a sufficient quantity of water. By this seething, the brown coloring matter is mostly removed, and the cloth begins to assume the fine tint which characterizes Turkey-red dyed cloth. It is still further improved by the next process.

15. Five or six pounds of soap, and from sixteen to eighteen ounces of protochloride of tin in crystals, are dissolved in water in a globular boiler, into which the cloth is put. The boiler is then covered with a lid which fits close, and the ebullition is conducted under the pressure of two atmospheres, or at a temperature of 250·5°. The boiler is furnished with a safety valve and a small conical pipe, the extremity of which has an opening of about three-tenths of an inch in diameter, from which there issues a constant stream of steam during the operation. The salt of tin is found materially to improve the color. Probably the oxide of tin combines with the oleaginous acid of the soap, fixed in the cloth. This insoluble soap doubtless unites with the red coloring matter of the madder, and alters the shade.

16. After all these processes, the cloth is spread out on the grass, and exposed to the sun for a few days, which finishes the clearing.

Such is a sketch of the Turkey-red dyeing, as practised in the principal works in Glasgow. Many attempts have been made to shorten these tedious processes, but hitherto without success. The impregnation with oil, or rather soap, is essential. If one, two, or three immersions be omitted, the red is inferior in proportion to these omissions. Doubtless this soap combines with, and remains attached to the cloth. And the same remark applies to common soap.

Cloth bleached by means of bleaching powder does not produce a good red. Doubtless the fibres of the cotton wool combine with lime, or rather with sulphate of lime, which, by decomposing the oleaginous soap, prevents it from combining with the cloth. But cloth bleached by the old process—namely, boiling in lie or soap, and exposure to the action of the sun, answers perfectly. The colors would be as good without the galls as with them. But there would be considerable difficulty in sufficiently impregnating the cloth with the alum liquor, without its being previously passed through the gall decoction, especially if the cloth be in the least degree greasy.

French Process.—The following process is given on the authority of M. PERSOZ, as generally practised in France at the present day:—

1. *Oiling the Goods.*—Assuming that the goods to be dyed are 1000 kilogrammes—2200 pounds—of cotton, and that they have been previously well washed and scoured in a soap bath, a liquor composed of the following ingredients is employed:—1287 to 1430 pounds of fat oil, 3300 pounds or 330 gallons of water, holding in solution 20 to 22 pounds of carbonate of potassa.

The oil, the water, and the carbonate of potassa, in these proportions, are divided into three equal parts, with which three parts of white liquor are formed successively as required, incorporating with the oil in small portions at a time the quantity of alkaline solution necessary to produce an emulsion. One-third of the goods to be oiled is padded in the first portion of this white liquor, and after this operation the pieces are laid together in a heap in a fresh and cool place, where they are left for ten to twelve hours; they are then put to dry in an atmosphere heated to 140° Fahr.

While this desiccation of the first portion of goods is in progress, operations are commenced on the second, which are passed into the second portion of white liquor; and when these are soaked, macerated, and put to dry, the same operations are performed with the third portion of goods in the remaining portion of white liquor. By this means the process is carried on without intermission; for, while the pieces last padded are lying at rest, others are in the drying-room, and others are being steeped in the liquor.

After each padding in the white bath, followed by the lying of the goods in a heap, and the subsequent drying process, the different portions of goods are returned to their respective white liquors, in which they are again worked. When the bath begins to fail, either a little tepid water is added, or a certain quantity of *old white liquor* proceeding from the washings; and this operation is repeated several times, according to the quantity of oil which it is desired to fix on the stuff.

The number of paddings in the white bath, which are always performed in the same manner—that is to say, followed by a period of rest, and then desiccation in a heated atmosphere—is generally seven or eight; the next process is what is termed the *degraissage*, or the removal of the superfluous oil, which is performed by macerating the goods twice, successively, for twenty-four hours each time, in a solution of carbonate of potassa at 1·2° Twaddle. The liquid which is wrung or pressed out of them constitutes the *old white liquor*, which is employed again in the oiling operations. The goods being carefully rinsed, are now ready to receive the galling.

Galling or Mordanting.—This operation is performed on two occasions: first, before the first maddering, and again before the last maddering.

Twenty-two pounds of bruised gall-nuts are subjected to several boilings till well drawn; and sufficient water is added to the product, to form in the whole about sixty-six gallons, in which thirty-five pounds of alum are dissolved with the assistance of heat. This liquor is introduced hot into the padding machine, and kept at the temperature of about 160° Fahr. during the whole time that the goods are worked in the bath. This quantity of gallo-aluminous liquid is about sufficient to mordant one-half of the goods under treatment—that is to say, 500 kilogrammes, or 1100 pounds, of cotton. On taking the goods from the padding machine, they are suspended for two days in a drying-room heated to about 112° Fahr., and then passed into a hot concentrated bath of chalk. As there is a large proportion of undecomposed alum on the cloth, and the base of which only becomes adherent by the intervention of saturating substances, if the goods were unequally immersed in this bath, there would necessarily follow infiltrations and flowings, producing belts or lines which would entirely destroy the beauty of a fine red ground. Care must, therefore, be taken to avoid this. The mordant being thoroughly fixed, the goods are washed, and present a fawn-colored appearance.

The Dyeing.—The dyeing is performed on ten pieces at a time, with proportions of madder which vary according to the breadth and length of the pieces, from thirteen, fifteen, seventeen, to twenty pounds a-piece. As in the preceding process, the madder is divided into two equal portions. That which is to serve for the first maddering is mixed with the quantity of water required—330 to 400 gallons—and the ten pieces are introduced into this bath, brought to a tepid state, and are kept in it three hours, progressively raising the temperature during two hours and three-quarters, till the bath arrives at a state of ebullition, which is not to be continued more than a quarter of an hour. On coming out of this bath, the fabric is washed, then submitted to the action of the cleansing machines, rinsed, and dried.

Second Galling or Aluming.—After this first maddering, steep again in the gallo-aluminous preparation; dry, and pass into the chalk bath, as after the first galling.

Second Dyeing.—This dyeing is performed in the same manner as the first, but without the addition of chalk, enough of which remains in the goods.

First Clearing.—This first clearing, as well as those that follow, is performed in the close boiler, filled two-thirds with water, containing in solution—

13 pounds of soap,
3½ pounds carbonate of potassa.

The boiling must be continued eight hours.

Second Clearing.—This is done with—

14½ pounds of soap,
14 ounces chloride of tin.

Third Clearing.—Same as the foregoing.

After this third clearing, which is only required for very lively reds, the goods are exposed for some time to the air; and after this exposure are worked through a bran bath, which exalts the brightness of the color. The red is then finished.

The process which has just been described is slightly modified by some French dyers; thus, as a long experience has proved that the oil is better fixed in the stuff when the drying is not performed too rapidly, there are some who, when the season does not admit of exposing the goods to the air, heap the pieces together, after the oiling, in a drying-room heated to 95° Fahr., taking the precaution to turn them over from time to time to prevent their becoming heated to an injurious extent. Some French dyers also have introduced the use of ox blood, employing it in the proportion of forty pounds to one hundred pounds of madder.

PERSOZ gives the subjoined process, as one which had long been employed with success by M. FRIES of Guebwiller:—

The cottons to be dyed were lixiviated in lime, passed into acid at 1·2° Twaddle, washed in the dash-wheel, submitted to the action of a lie of carbonate of soda, containing fifty-three pounds of the soda salt to eight hundred and eighty pounds of the cotton, and lastly, again washed and dried.

For the treatment of one hundred pieces of calico of forty yards in length, or about four thousand yards, two large wooden vessels, A, B, were used, each of one hundred and ten gallons capacity. Ninety gallons of water, holding in solution thirty-six pounds of carbonate of potassa, were introduced into the vessel, A, and into the vessel, B, one hundred and ninety pounds of fat oil, slightly heated if in winter, and to which the alkaline liquor of the vessel, A, was added by small portions at a time, and carefully stirring till the oil formed a perfect emulsion. The pieces were then padded in this emulsion, and if the operation was conducted with care, the quantity of white liquor formed was sufficient for the one hundred pieces. These were then put into a heap till next day, or exposed on the grass in fine weather; otherwise, they were dried in a moderate heat, not exceeding 105° Fahr. On coming from the drying-room, they were padded again in a second white bath, exposed on the grass in favorable weather, or, if the weather was unfavourable, put again into the drying-room—heated this time to 113° or 115° Fahr.

These two white baths having been given, what remained of the liquid in the vessel, B, was poured into the vessel, A, which was filled up with water proceeding from the operation for removing the superfluous oil, or, in default of that, with water holding in solution carbonate of potassa, marking 1·2° Twaddle; in this species of white liquor the goods were worked five or six times successively, taking care to expose them on the field after each operation; they were then put into the drying-room, gradually raising the heat, but not to exceed 120° Fahr.; after the last immersion, they were kept in the drying-room for eighteen to twenty hours, at a temperature of 100° to 120°.

The Degraissage.—This operation for removing the superfluous oil was performed as follows:—On withdrawing the goods from the stove, they were put into a vessel, and sprinkled with enough of tepid water—at 90° Fahr.—to wet them thoroughly; a workman with wooden shoes then tramped them well, turning them over three or four times to multiply the points of contact, and lastly wrung them, carefully collecting the lactescent water so expressed. This is termed *the water of degraissage*. After this operation, the goods were submitted to the action of cleansing machines, in which they were rinsed till the water came out perfectly clear. They were then dried, to receive the galling or mordanting in the next process.

First Galling.—Fifty-five pounds of nutgalls were boiled four hours in forty-four gallons of water, and the decoction left to settle. The clear portion was then taken, and enough of water added to it to form one hundred and ten gallons, dissolving in this decoction—

110 pounds of purified alum, and
8 pounds of acetate of lead.

The goods were put into the padding machine in this gallo-aluminous decoction, used hot, but taking the precaution not to give too much pressure. When thus padded with mordant, they were exposed in a drying chamber to a moderate temperature, where they were left at rest three days, and afterwards passed into a chalk bath at 90° Fahr. This last operation was performed in a tub on four pieces at a time, to which four double turns were given, employing for the first four pieces four and a half pounds of chalk, and only two and a quarter pounds for each of the other four. Nevertheless, to prevent the accumulation of too much chalk in the bath, it ought to be renewed after passing twenty-four pieces through it. On coming out of the bath, the goods are washed in the dash-wheel.

First Maddering.—For eight pieces of forty yards in length, the bath contained—

70 pounds of Palus madder,
4½ pounds of Sicilian sumach.

The temperature of the madder bath was regulated so as to reach 212° in two hours and a half, and was kept at this temperature one hour, which gave for the duration of the dyeing three hours and a half. After the maddering, the goods were rinsed, carefully scoured, and dried in the air or on the grass.

Second Galling or Aluming.—In this operation the process of the first galling was exactly repeated; the mordant was the same; the only precaution to be taken was, not to work the goods at too high a temperature: it should be such that the hand may be held in the solution without inconvenience. The goods were then left at rest three days; then passed into chalk, and rinsed without scouring.

Second Maddering.—This was given like the first, and followed by a rinsing in running water.

First Clearing or Brightening.—In a covered boiler, containing three hundred and thirty gallons of water, the following ingredients were dissolved:—

17½ pounds of carbonate of potassa,
4½ pounds of white soap.

Ten pieces, oiled and maddered, were put into this liquid, kept at boil five hours, and, on being taken out, rinsed in running water.

Second Brightening.—Still using the same covered boiler, the same number of pieces were put into a similar quantity of water with these ingredients—

17½ pounds of soap,
3⅓ pounds of carbonate of potassa,
1 pound of chloride of tin.

This liquid was brought to ebullition, and kept in that state five or six hours.

Third Brightening.—In the same quantity of water were put only—

9 pounds of soap,
14 ounces of carbonate of potassa,
14 ounces of chloride of tin.

After five hours' ebullition, the goods were taken out of the covered boiler, scoured with the washing machines, and exposed on the grass eight to ten days, turning them over three or four times daily.

When the cloth which had passed through these different operations was intended to be sent into the market with a plain ground, it was passed into a water slightly acidulated with hydrochloric acid, and then rinsed.

When the goods to be brightened were sparingly oiled, they received only two brightenings—the first with nine pounds of soap, and five and a half pounds of carbonate of potassa; the second, with ten pounds of soap, and fourteen ounces of chloride of tin.

Such was the course followed and the proportions of ingredients used for a first portion of the goods; for the remaining portions the quantity of oil was diminished, and also that of the carbonate of potassa, in consequence of using the waters of *degraissage* from the preceding operations. The quantities employed were therefore—

For the second portion,.......35½ pounds of oil,
For the third portion, ...33 " "
For the fourth portion,........28½ " "

adding to the water of the vessel, A, one and a half ounces carbonate of potassa for each pound of oil introduced into the vessel, B.

The two preceding processes for dyeing Turkey-red differ only in the degree of temperature at which the desiccation is performed, in the quantity of acetate of lead added to the alum to give it a greater tendency to fix itself on the stuff, and, lastly, in the addition of sumach to the madder bath. These differences, however trifling they may appear, often lead in practice to results, the importance of which entitles them to consideration.

SWISS TURKEY-RED PROCESS.—Switzerland has long enjoyed a merited celebrity for its Turkey-reds, having been enabled, by the application of superior intelligence to the subject, to struggle successfully against unfavorable conditions, and to send into the market products which bear advantageous comparison with those of any other country, both in regard to price and quality. This success, says PERSOZ, may be attributed to the great reduction which has been effected by the dyers of that country in the quantity of oil and weight of madder employed. The quantity of oil formerly used was at least equal to half the weight of the cotton, whereas it is now reduced to a fourth; and the madder used, from being double the weight of the cotton, is now reduced by many dyers to the same weight—

that is to say, one hundred pounds of madder, instead of two hundred pounds as formerly, are now taken for dyeing one hundred pounds of cotton; and yet the results leave nothing to desire.

There is not anything essentially new in the process followed in Switzerland; its excellence consists only in the application of several scattered data, the uniting of which in the same process conduces to results of the most satisfactory character. It is to the same circumstance that Eberfield owes the superiority of its products in this department of dyeing.

Oiling.—In the process commonly followed in Switzerland, the white baths are given at a temperature of 80° to 85° Fahr., adding to the ingredients, already stated as used in the French process, cow dung in a state of fermentation.

For a portion consisting of two hundred kilogrammes, or four hundred and forty pounds, of cotton, the following ingredients are employed:—

29½ pounds of fat oil,
55 gallons of carbonate of potassa, in solution, at 39·2° Twaddle.
13½ gallons of cow dung, fermented, and brought into a pulpy state with a little cow urine.

The cow dung is mixed with fifty and a half gallons of water heated to 98° or 100° Fahr., the oil is added, and the whole is formed into an emulsion by introducing, in successive portions, four and a half gallons of carbonate of potassa in solution, at 39·2° Twaddle. The temperature of the liquid being then brought to the desired point, the goods are padded in the usual manner. They are then introduced into a wooden trough, in which they are left to themselves from twelve to eighteen hours to set up a fermentation, which is often carried to such an extent, that it is not a rare occurrence to see myriads of small worms developed in that short period. They are then dried in the open air, and exposed during eight or ten hours in a stove heated to 145° Fahr.

After this first bath, they receive a second, a third, and a fourth, always fresh prepared, adding to the residue of each of them the proportions indicated above, so that, after these four oilings, the four hundred and forty pounds of cotton have consumed—

117½ pounds of oil,
220 gallons of carbonate solution,
54½ gallons of cow dung;

and after each bath, the goods are exposed, first to the air, and then in the stove heated to 145°.

These four oilings are followed by other four, performed in the same manner, but in tepid water, holding in suspension the residues of the four original white baths, and the *old liquors* from the *degraissage.* After each of these immersions, they are dried in the open air and stoved, as after each passage through the white bath, but at lower temperatures—namely, at 140° Fahr. after the fifth and sixth baths, and about 132° after the seventh and eighth, with which this operation is concluded.

The next process is the *degraissage* or *unoiling*, by the method indicated in M. FRIES' process. The *old liquor* is collected during this operation, and the goods are then cleaned by the dash-wheel, from which they are taken out to be wrung, and then dried in the stove at the temperature of 120° Fahr.

Galling.—The galling is also performed in two operations; for the first, in which no alum is used, the following ingredients are boiled for one hour in forty-four gallons of water:—

16½ pounds gall-nuts,
14 pounds Sicilian sumach.

To allow this decoction to clear, it is left to itself for twenty-four hours after passing it through the sieve; then decanted and heated to 110° Fahr. The goods are then padded with this liquor, dried in the open air, and afterwards stoved at the temperature of 120°.

The second galling is performed exactly in the same manner as the first, except that the sumach is kept back and alum added.

In forty-eight and a half gallons of water heated to 115°, dissolve—

47 pounds of purified alum, saturated with
77 pounds of carbonate of potassa, in solution, at 39·2° Twaddle.

After passing the goods through this bath, they are wrung or pressed out, and left in a heap during six hours; they are then put into the stove—heated to 80°—to be dried, without a current of air; they are next *ventilated* for three days, and afterwards passed through the stove heated to 120°. Then, as the alum is only partly saturated, they are passed through a chalk steep raised to the temperature of 120°, using five and one-fifth pounds of chalk for forty pounds of cloth. When rinsed and dried after coming out of this bath, the goods are ready for dyeing.

The Dyeing.—This is performed in one operation, taking for forty-four pounds of the fabric from

44 to 66 pounds Palus madder,
6 pounds sumach,
3·74 gallons ox blood.

The temperature of the bath is progressively raised during two hours and a half, and the boiling is kept up half an hour; the pieces are then rinsed, and submitted to two brightenings, which they receive in the covered boiler, where they are boiled six hours, namely:—

For the first operation, with eleven pounds of soap, sixty-six pounds of carbonate of potassa, and forty-four pounds of chloride of tin.

For the second brightening, with eleven pounds of soap, forty-four pounds of chloride of tin, and two hundred and eighty-six pounds of nitric acid.

After these brightenings, the goods are exposed on the grass for two or three days, and then passed into a boiling bran bath.

This process is essentially distinguished from the preceding ones, inasmuch as all the operations tend to provoke a fermentation among the different substances which are found in presence of each other, and to determine the metamorphosis of the fatty body. While recognising the necessity of reaching a certain degree of heat, it evinces, at the same time, a full appreciation of the importance of giving due scope to the action of the air. This action is exerted so much the better on the cotton in proportion as the latter contains a certain quantity of water, whilst a too rapid drying withdraws it from the influence of the agent which is called to perform the principal part in the reaction. It is doubtless for this reason that the dryings in the stove-chamber are always preceded by exposures in the open air, which only produce a slow desiccation.

TURKEY-RED PROCESS WITH NITRIC ACID.—In the process which has just been detailed, a small portion of nitric acid is used in the brightening; but in that which follows, it enters in considerable quantity into the oiling. This process has been used with good results by M. GASTARD, to whom dyers are indebted for the direct application of the coloring matter of madder. The following are the details of his method, as communicated by that gentleman to M. PERSOZ:—

Preparation of the Goods.—After leaving the goods for a period of twenty-four hours in water heated to 70° or 80° Fahr., they are worked through it, and then boiled four hours in water containing sixty-six to seventy gallons of old white liquor; they are left in the same boiler till next day, when they are again well sodden, rinsed twice, and dried.

For sixty pieces of cotton weighing two hundred and thirty-three to two hundred and forty pounds, the white bath is composed as follows:—

7·7 pounds of fat oil,
2·6 gallons of sheep or cow dung.

Oiling.—With the substances above-mentioned, incorporate a solution of carbonate of potassa at 5·4° Twaddle, till a perfect emulsion is produced, sufficient to impregnate the whole of the fabric. Pad the pieces in this emulsion, expose them to the air in the sun, if the weather permit; if not, hang them up to dry. When the desiccation is nearly finished, introduce them for four or five hours into the drying stove, heated to 150° or 160° Fahr.; on coming out of the stove, they are twice worked through water, acidulated with nitric acid at 1·2° Twaddle, and then dried in the air, but not now in the hot stove, where they would infallibly be burned. They afterwards receive—

1. A second white bath like the first, followed by exposure to the air and in the hot stove;

2. A second passage through nitric acid at 1·2° Twaddle, followed by a desiccation in the open air;

3. A third white bath similar to the first, and followed in like manner by an exposure to the air and in the hot stove;

4. A third passage through nitric acid at 1·8° Twaddle, followed by a desiccation in the open air;

5. A fourth white bath similar to the first, followed by exposure to the air, and stoving at the temperature of 150° to 160° Fahr.;

6. A fourth and last treatment with acid, to which succeeds a desiccation in the open air.

For the last two oilings the dung may be omitted.

Degraissage.—After all these operations, the goods are passed into a solution of carbonate of potassa at 6° Twaddle; they are then wrung out, collecting the old white bath, dried in the air, left to steep in water for two hours, and, lastly, rinsed and dried twice over.

Galling.—The galling is also given in two operations: the first, in a perfectly clear decoction of thirty-three pounds of Sicily sumach; the second, in a decoction of nut-gall.

In both operations the liquor is used hot, and the two are followed by a desiccation.

First Aluming.—In the quantity of water required to impregnate these two hundred and forty pounds of cotton, dissolve—

26·8 pounds of alum, and add
1·65 pounds of acetate of lead,
4·4 gallons of solution of carbonate of potassa at 5·4° Twaddle;

pad the goods in the liquor, which should be used cold, and after it has cleared by settling, it ought to indicate 5·4° Twaddle. The goods are then laid in a heap, and left in that state twelve to fifteen hours, after which they are dried, and then put to steep in water four hours; finally, they are rinsed twice in running water.

First Maddering.—To madder the sixth part of the quantity of goods indicated, or about ten pieces, use—

37 pounds of madder,
2·2 to 2·6 gallons of ox blood,
4·4 to 7·7 pounds of sumach.

The dyeing is effected in three hours, gradually raising the liquid to the boiling point. On coming out of this bath, the goods are washed, scoured, and dried.

Second Aluming.—This aluming is performed in the same manner as the first, except that, when the goods are dried, they are passed, at the temperature of 120°, into a bath of cow dung impregnated with chalk, and then rinsed.

Second Maddering.—Same as the first.

First Brightening.—For thirty pieces, or one hundred and sixteen to one hundred and twenty pounds of the stuff under operation, pour into a boiler of suitable capacity, half-filled with water, eleven to thirteen pounds of carbonate of potassa, and sixty-six to seventy gallons of old white liquor; boil four or five hours, and leave the goods in the boiler till next day; then take them out to be rinsed and beaten; and, lastly, spread them on the grass, where they are left exposed four to five days according as the color developes.

Second Brightening.—Pour into the clearing boiler, along with the quantity of water required, a decoction of 2·2 pounds of bran; when the liquid is in full ebullition, add to it a solution of 16·5 pounds of Marseilles white soap, and then, by small portions at a time and stirring well, a solution of one pound of chloride of tin, in one gallon of water, acidulated with half a pound of hydrochloric acid, and one and a half to two ounces of nitric acid, according as it is desired to give to the fabric a more or less scarlet tint. The goods, previously wetted, are then introduced into the boiler, in which they are boiled for an hour, and left in it till next day.

PERSOZ remarks, that if chalk does not appear prominently among the agents employed in this process, this may be attributed to the circumstance that the waters employed by M. GASTARD were essentially calcareous. He calls attention, at the same time, to the fact, that the consumption of oil is greatly reduced by this method, since thirty pounds of that substance suffice for the oiling of two hundred and forty pounds of cotton; and what is remarkable, he affirms that, notwithstanding the small quantity of fatty matter employed, he found the results fit to be compared with the finest samples produced by the ordinary methods.

VIOLETS ON THE TURKEY-RED SYSTEM.—By mordanting the oiled goods with an iron, instead of an aluminous mordant, violets of great beauty and peculiar lustre are obtained. For this color, it seems to be essential to employ sheep dung, and to pad the cloth with an iron mordant at its maximum of oxidation; the nitro-sulphate is used for this purpose. PERSOZ affirms, as the result of his own experience, that very fine violets may be obtained by mordanting the oiled goods in a solution of ferric-sulphate, obtained from the calcination of ferrous-sulphate, and marking 4° Twaddle, mixed with 7 to 8 per cent. of chloride of ammonium. On coming out of this bath, the goods are dried, then passed into another bath of arseniate of lime and potassa, as in fixing ordinary mordants.

RATIONALE OF THE TURKEY-RED PROCESS.—This process is far too important to be passed over without some attempt to explain the action of the different ingredients employed, which result in producing the most beautiful and permanent of dyes. One of the highest authorities on this subject is M. PERSOZ, and therefore the Editor cannot do better than subjoin a summary of the observations of that eminent practical chemist on the different parts of the process.

First, with reference to the *oiling*, PERSOZ remarks that to oil the goods for this purpose, it is not sufficient to cover them with some fatty body, since experience proves that a spot of oil or grease, which is not modified in some manner, acts as a resist or reserve on the part of the stuff which it covers, and prevents the mordants of iron or alumina from adhering to it. The nature of this body must therefore be modified by the aid of alkalies or alkaline compounds, under the threefold influence of water, heat, and air. Nevertheless, there is not in this case a simple saponification, as some have maintained; for if so, it would be sufficient to use soaps having for their base olive or common oil, to impregnate the fabric with these, and then to set the fatty acids at liberty, in order to bring the goods to a state capable of being dyed a rose color in a madder bath. But this is not the case, for the oiling operation never succeeds better than when carbonate or bicarbonate of potassa or soda is used, the saponifying action of which substances at the common temperature is not to be compared with that of caustic alkalies. The cause must therefore be sought in another direction. The oil and the bicarbonates are doubtless the principal substances of this operation; but the former must not be a drying oil—it must be of that kind which is termed in commerce *fat oil*, and use must be made of certain matters, such as sheep or cow dung, which it has not been found possible to dispense with. Gallipoli oil is generally used in this country; that employed on the Continent is of the same nature, and is termed in France *huile tournante*, from its tendency to become rancid, and from the circumstance that, when mixed with a solution of carbonate of potassa or soda, it immediately produces a milky emulsion, colored slightly yellow. These oils are obtained from olives which, before being pressed, are submitted to the action of hot water, and are consequently strongly charged with extractive matters.

After being padded with the white liquor, consisting of a mixture of the fat oil, bicarbonate of soda or potassa, and excrementitious matter, the goods are dried, as has been stated, either by exposure to the sun, or in the hot stove. During this drying process the fatty body experiences a modification which renders it insoluble in weak alkalies, and acquires in a very high degree the property of strongly adhering to the fabric; but, as this modification begins at the surface of the goods, and the external portion of each coating of the white liquor is easily detached, not having entered into combination with the stuff, the operation of passing through the white bath is repeated till the fabric is sufficiently impregnated with the oil. The number of passages through the white liquor is regulated both by the season and the temperature of the stove in which the goods are dried, as well as by the nature of the oil employed. Formerly, eight to fourteen baths were given; the number is now much reduced.

The heat of the sun and of the weather exercises a very great influence on the goods when dried in the air. In autumn, in winter, and in spring, much more difficulty is experienced than during the summer season in modifying and fixing the fatty substance. When the goods are exposed in a drying chamber, the effects of the artificial heat are not less marked, and if the proper temperature is not attained, important differences are observed in the intensity of the shades produced.

The modification which the fatty substance undergoes when it is submitted, in contact with the fabric, to the threefold influence of the air, of heat, of the alkaline carbonates—the products into which it is metamorphosed—in a word, the rationale of this mysterious operation—have not been satisfactorily explained. PERSOZ remarks that there is no question more profoundly interesting to the chemist, and that to the importance which it presents in a theoretical point of view may be added the practical consideration, that he who should succeed in discovering a method of modifying at pleasure fatty bodies of this nature, could not fail to realize a very large fortune by the discovery. M. WEISSBERGER, one of PERSOZ's pupils, found that the oiled stuffs, which give up their modified fatty substance to oil of turpentine, yield it also to acetone; and by availing himself of this property, and afterwards evaporating the acetone in the water-bath, he found as the residue a viscous liquid of a fatty nature, which separated itself into two strata, the one solid, the other liquid, and capable of being kept a long time in the same state. The modified fatty substance having been extracted by the acetone from the cloth which had passed through the white bath, M. WEISSBERGER ascertained that, in proportion as this substance was abstracted, the cloth lost its power of attracting and combining with the madder dye. Desirous of knowing whether this viscous liquid still possessed the essential property of the fatty body by which it was generated, he saponified it with powerful bases, and finding no trace of glycerin in the products of the saponification, he was forced to conclude that this substance had disappeared. Lastly, he showed, and M. PERSOZ himself repeated and verified the experiment several times, that it was only necessary to apply on a stuff, a suitable quantity of this modified fatty body, so abstracted by acetone, to obtain with the madder the deepest and purest shades; and from his experiments on this subject, M. PERSOZ concludes, that if one ever succeeds in preparing this fatty body directly, the use of the aluminous mordants may be dispensed with. This observation, says that chemist, which seems at first rather extraordinary, is supported by another made by M. CHEVREUL on a particular *Turkey-red* which he analysed, and from which he could only extract a very small quantity of alumina, although a large proportion of that substance had been used in the dyeing process. If the glycerin disappears in this operation, it is by undergoing an oxidation and a transformation, the former being produced by the united action of the air and the conditions of temperature at which the oiling is performed; the latter by the use of azotised substances indispensable for putting the organic matter in motion. M. PERSOZ thinks, that to these substances must, doubtless, be attributed in great part the necessity of using excrementitious matters; he conceives also that the phosphates which exist in the latter in considerable quantity, may exercise an important influence.

The object of the alkaline washing, which follows the white baths, is to remove that portion of the fatty body which has not undergone the requisite modification, and also that portion which, although modified, is not in a state of adherence to the fabric; for if these portions of the organic mordant were not removed, the inorganic mordant next applied would not be fixed on the goods in an equal and uniform manner, in consequence of the unmodified fatty substance acting the part of a resist.

It is generally ackowledged that in the process of oiling, the fatty body is better modified and fixed on the stuff, in proportion as the latter is longer exposed to the air with the humid oily preparation upon it, but under protection from the rain and the too powerful action of the solar rays, and also in proportion as the stoving is conducted at the proper temperature. It appears best to impregnate the fibre only at its surface, for otherwise the shade becomes too deep, and it is difficult to pass it through the brightening process without diminishing the liveliness of the tint. By cutting a piece of cloth which has been dyed the finest red, it will be seen that the interior of the fibre is white, which proves that the oil and the aluminous mordant penetrate only imperfectly into the centre. This application of the color to the surface of the stuff gives a peculiar lustre to the shade, which the colorless or slightly colored interior of the cloth naturally renders clearer and more transparent.

When the goods have been oiled, great care must be taken to prevent the slow or spontaneous combustion of the fatty body with which the stuff is charged: in the former case, the fabric is always more or less injured; in the latter, the establishment is in danger of being set on fire—a calamity which has sometimes happened from this cause.

The slow combustion, as well as the spontaneous, proceeds either from too much oil in the stuff, or from too little carbonate of potassa having been employed to saturate it. The first is determined by the exposure of the goods in too powerful sun-heat, or by the heat which is developed from their lying too long in a heap; the second is produced by the action of the oxygen on the free oil which covers the goods when in the stove. Turkey-red dyers, who employed, in other respects with success, drying oils from seeds, were compelled to give up the use of such oils in consequence of the accidents of this kind to which they led.

As it is demonstrated by BOUSSINGAULT'S experiments, that cow urine contains alkaline bicarbonate, it might be worth trying whether this substance might not be successfully applied for the oiling of goods. It contains, likewise, principles essentially fermentable, and would therefore be better fitted to play the part of a ferment, than the water charged with alkali which is used at present. In connection with this subject, PERSOZ expresses his belief that cow dung may act in virtue of the fatty body which it contains, and that the nourishment given to the cow may produce a sensible effect on the operations in which that excrement is used, by modifying the nature of the fatty body contained in it, and which will vary with the kind and age of the herbage on which the animal is fed.

Thus much with reference to the *oiling*, or the organic mordanting, which constitutes the special characteristic of the Turkey-red process. The next subject to be considered is the *real mordanting*, or the application of the inorganic substances. When the goods have been perfectly scoured after the oiling operations, which is known by wringing them at one end, and observing whether the water comes out perfectly clear, they are covered evenly over with inorganic mordant. Alum or acetate of alumina is used for red mordant, nitro-sulphate of iron for violet mordant; but these preparations do not perform what is required of them in the same conditions, for the affinity of the modified fatty bodies for alumina, however great it may be, is yet insufficient to determine the total decomposition of the alum, and the complete fixation of its base on the stuff, for which purpose it requires to be saturated. Hence, while some dyers are satisfied with padding their goods in acetate of alumina, to give them the proportion of that base necessary for the fixation of the coloring matters, those who use only alum—the general practice in this country—must necessarily interpose other bodies to favor the adherence of the alumina to the stuff. They have, therefore, recourse to galling, perhaps without being aware of its use, although it is in fact a preliminary operation to which all goods were formerly submitted that required to be mordanted. It follows that there are two methods of mordanting, one of which consists in padding the goods purely and simply with acetate of alumina, the other in impregnating them with a decoction of nutgall or sumach, an operation properly termed *galling*, and which is most generally confounded with that of aluming, by previously making an astringent decoction which should mark from 11° to 12° Twaddle, and in which the alum is dissolved. M. DANIEL KOECHLIN, who used acetate of alumina, arrived at the conviction that the interposition of the nutgall has no influence on the shade of the red; its only advantage, he believed, was in giving the color more solidity, especially when the goods have to pass into a solution of bleaching powder. When padded with the gallo-aluminous solution, they are dried and passed into a chalk bath, to saturate the alum, and render it cubical, so as to be capable of yielding up its base to the stuff. It is remarkable, says PERSOZ, that the alum is not first saturated with the chalk, which, being absorbed in large quantity, would form a very soluble compound, yielding the alumina readily to the goods. When acetate of alumina is used, the mordanted cloth is dunged in the usual manner, and then passed through a dilute chalk liquor.

The next process is the *dyeing* or *maddering*, which is not performed in precisely the same manner in all establishments. In some it is done at one operation, in others at two; the first dyeing is termed in France the *retirage*, and the second *bouillissage*. Again, the proportions of madder required vary between a quantity equal to the weight of cotton employed and twice that quantity, along with a certain proportion of chalk. It is impossible, says PERSOZ, to obtain fine rose tints which have no tendency to pass to a violet shade, without the intervention of this last-named substance. The effect of lime has long been known to give a peculiar beauty and durability to colors.

Independently of the chalk, a certain quantity of sumach is often mixed with the red, to economise the madder. It results, in fact, from the experiments of J. M. HAUSSMANN, that an addition of sumach and nutgall to the madder bath contributes to the development of a much larger quantity of coloring matter. But M. EDOUARD SCHWARTZ, who has corroborated this advantage, so far as regards the amount of color produced, is convinced that the reds dyed in this manner are infinitely less fixed, and consequently ill fitted for those styles which required to be passed through the chloride of lime liquor.

Besides the sumach, bullocks' blood, in the proportion of one-fourth of the madder employed, is sometimes added to the madder bath; or a certain quantity of Cologne glue, which is mixed with the sumach in equal parts, and amounts to the fourth part of the madder.

In some dye-houses the maddering is performed over an open fire, in others the vessels are heated by steam; but as, for this kind of dyeing, the temperature must be kept at the boiling point, and there is a large condensation of water, some dyers have recourse to a convoluted pipe for circulating the steam to heat the bath.

The *brightening* constitutes the last series of operations, and these will be considered first with reference to the agents employed, and secondly as regards the apparatus required.

The brightening or clearing of Turkey-red differs essentially from that of ordinary reds, in this respect, namely, that for common reds, the first operations tend chiefly to fix the fatty body of the soap, and to render it a constituent part of the lake which is formed at the surface of the stuff, to give it in this way all the stability and vivacity possible; whereas, in the brightening of Turkey-red, the fabric being saturated with fatty matter, the effect to be produced consists, first, in removing the excess of that fatty matter, and secondly, in substituting for the alumina—the base of the red lake—a certain quantity of oxide of tin, which modifies its shade and gives it that fiery tint which is characteristic of the Turkey-red, and is so opposite to that of the common red, which inclines to amaranth.

The substances which serve for the brightening are carbonate of potassa, soap, and chloride of tin. Generally, the soap and carbonate only are used for the first brightening, and the chloride of tin is introduced in those that follow. After the first operation, the soap and chloride of tin are alone employed. The part performed by these substances is easily understood: the carbonate of potassa and soap effect the solution of the fatty body in excess, and dissolve at the same time a pretty large proportion of the coloring matter which is found remaining in the bath. As regards the chloride of tin, it undergoes decomposition, and oxide of tin is produced, which displaces a portion of aluminous oxide, takes its place, becomes oxidized, and converts the red into a fiery shade, by reason of the orange tint which the compounds of tin assume in the madder bath.

PERSOZ suggests that soap might be dispensed with in the first brightening, and its place supplied by carbonate of potassa at the pressure of half an atmosphere. This salt does not injure the fabric, and furnishes very fine colors. It might also be useful to attend to the observation made by M. E. SCHWARTZ, that on treating with a concentrated solution of bleaching powder a small piece of Turkey-red which had just been dyed in the madder bath, an orange-red was obtained which had no analogy with that produced by the ordinary brightenings, whilst a similar piece, treated hot in the same solution, previously decomposed by carbonate of soda, gives, if the proportions have been well observed, a red as fine as that which has been brightened with soap.

It is known that, in the clearing or brightening of common reds, the treatments with soap produce no favorable effect beyond certain limits, the lake being supersaturated with fatty matter, and that, to render them more efficacious, the action of air or acids must be brought to bear. Now, the red upon oiled goods is precisely in the same state of supersaturation when submitted to the brightening process; would it not be desirable, therefore, on taking the stuffs from the madder bath, to treat them immediately with acids, and only to apply soap in the last place? It is perhaps to something of this kind that one may attribute the advantages which some dyers have found from impregnating the oiled goods with weak nitric acid.

When, after the clearing operations, the red assumes a rose shade, this is a proof that the cotton has not been sufficiently saturated with oil, or that the quality of this oil has not been suitable, or that the white baths have been mismanaged, or, lastly, that the desiccations have not been performed at the temperature required for the modification of the fatty body.

With reference to the apparatus used in the brightening processes, the liquor is heated in a covered boiler of about two hundred and twenty to two hundred and sixty gallons capacity, containing, with the requisite quantity of water and soap, any amount up to seven hundred yards of cotton goods, oiled and maddered; they are left to boil under a certain pressure from twelve to eighteen hours, and are brightened a second or even a third time, according to the degree of intensity which it is desired that the red should possess.

To avoid the loss of steam which results from the daily use of the common covered boiler, Schwartz has proposed a new arrangement for economising the waste steam. This arrangement is shown in Fig. 351. Contiguous to the common boiler, A, is placed another, B, which communicates with the former by means of a jointed tube, P, fitted with a stopcock, I, by which the steam disengaged from the boiler, A, passes into the boiler, B, under the false copper bottom, D. This false bottom is perforated like a colander, and rests on the support, E, on which the goods in this boiler are placed. Both boilers are furnished with safety-valves, M, M, with discharge-cocks for the steam, N, N, and with stopcocks below for discharging the fluid contents.

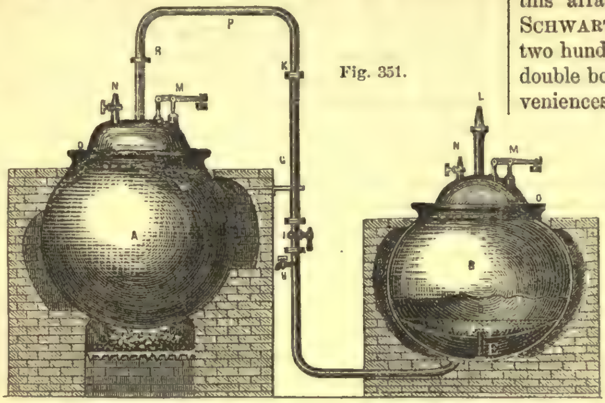


Fig. 351.

O is a flange, which, by arresting the water of condensation that runs down the lid, prevents it from falling on the heated sides of the boilers. The object of the stopcock, H, is to second the operation of the safety-valve, and to enable the attendant to watch the progress of the operation. When steam escapes on the opening of the stopcock, all is right; but when water comes out, this is a proof that a valve which is placed at R is not working, and that the steam must make a passage for itself by the safety-valve.

It is easy to work these boilers. When the quantity of water required for one operation has been pumped into the boiler, A, and brought to ebullition, the agents employed in the brightening process, and the quantity of goods to be subjected to their action, are introduced; the lid is then fixed on, with the pipe, P, attached to it, carrying at the joining, R, a valve which opens upward. The stopcock, I, is then opened, and the steam which passes into the boiler, B, brings the liquid in that boiler to ebullition in the space of three hours. The latter is then charged in the same manner as the first boiler, covered over, and the steam allowed to enter during seven hours. The goods in the generating vessel thus receive a boiling of ten hours; those in the other only seven hours. When the boiler, A, ceases to give out steam, the valve of the boiler, B, is shut, that no steam may be lost. The latter preserves so much heat that the goods may be left in it two hours longer, at the end of which period it has still a certain pressure. And as it is the custom to give a shorter time to the goods at the second and third brightening, the boiler, A, is specially employed for the first operations, which are kept up longer, and the boiler, B, for what is properly called the *rosing*.

Besides the advantage attending the circumstance that old copper vessels may be employed for the boilers, B, which do not receive the direct action of the fire, this arrangement affords a great economy of fuel. Schwartz attributes to it a saving to himself of two hundred and seventy pounds of coal daily. This double boiler system is not, however, without its inconveniences; it entails the necessity of preventing the condensation of the steam, especially in cold weather, by surrounding the boiler, B, with some non-conducting substance, such as powdered charcoal.

During the process of brightening, great care must be taken that the tube and safety-valve do not get out of order; negligence in these matters has often produced heavy losses, and sometimes even the death of the workmen engaged in conducting the operation.

Such is a general review of the process of dyeing Turkey-red, as conducted in almost all the establishments in which it is carried on, both on the Continent and in this country. Another process was proposed by J. M. Haussmann, which differs in some important particulars from any of the common methods; and therefore, though never applied on a very large scale, a short account of it may be useful. It consisted in dissolving one part alum in two parts warm water, and while in a state of ebullition introducing into this liquor enough of concentrated caustic potassa lie, to precipitate and redissolve the alumina of the alum. By cooling and allowing to settle, a great part of the sulphate of potassa was deposited, and the clear liquor being decanted off, he added, by small portions at a time, to thirty-three parts of this solution of alumina and potassa, one part of linseed oil, thereby forming an emulsion with which the goods were impregnated. The cotton, thus prepared, was dried under shelter from the rain in summer, and in winter in a hot chamber; after twenty-four hours they were rinsed and again dried; then they were padded in the alkaline emulsion a second time, quickly dried in the air, and so on till the stuff had received the number of emulsions required. M. Haussmann said that two impregnations of the alkaline solution of alumina mixed with linseed oil, sufficed for obtaining a fine red; but by continuing to impregnate the goods a second and even a fourth time under the same conditions as the first, the colors were obtained extremely brilliant.

By this process he oiled and mordanted his cottons at one operation, and had only then to proceed with the dyeing, which was performed in this case also with the addition of a quantity of chalk equal to one-sixth of the weight of the madder, and using thirty or forty times that weight of water. The dyeing was performed differently from the usual manner. He brought the bath gradually during the space of an hour to such a temperature as just admitted of the hand being held in it without inconvenience; he then left the cotton in it two hours longer, which gave a duration of three hours to the operation. After the dyeing, the stuff, being thoroughly washed and scoured, was passed through a bran bath, adding to it soap and carbonate of potassa, when it was desired that the goods should have a crimson-rose shade. HAUSSMANN affirmed that he obtained by this process reds which surpassed in beauty and brilliance those of the Levant, and which could in all respects bear comparison with even the best that were produced in France. His son, M. B. HAUSSMANN, entirely corroborated to M. PERSOZ all that had been stated by his father with reference to this process, but acknowledged, at the same time, that no extensive application had been made of it, because the results had never been favorable on a certain scale. This, to say the least, appears somewhat unintelligible.

Oiled Rose Grounds.—Besides the red and violet grounds obtained by the preceding processes, rose grounds are also given to oiled stuffs. For this purpose, after oiling the goods as equally as possible, and in the same way as for reds, suppressing sometimes one or two of the oilings, and then subjecting the goods to the usual *degraissage* process, two methods are followed. Some dyers then pass them into a very weak aluminous mordant, scour and dye in madder in the usual way; others, who by this method obtain weaker but much purer shades, put them directly into the boiler, in which they brighten the goods for red shades. The coloring matter that has been detached from the latter is found sufficient to saturate the organic mordant, and to give it the desired tint. For pale colors no process can be better; for if the cloth be saturated with oil, the quantity of aluminous mordant employed will always be too great, however weak it may be, and the shade will always be too deep. Now, to degrade it, would be to destroy its lustre, while, if the oiling be diminished, the tints will return more or less to ordinary reds, and will not stand the brightenings which are indispensable to bring them to the natural tone of the Turkey-red.

It now remains to add to the preceding details and explanations of the Turkey-red process, the following ingenious views on the subject, by Mr. JOHN THOMPSON of Glasgow, which first appeared in the eighth volume of the Annals of Philosophy, and which, in conjunction with M. PERSOZ's speculations already given, afford, perhaps, all the light that can be thrown on what Dr. BANCROFT termed, in 1794, an unaccountable process which chemical analysis does not elucidate:—

Silk and worsted, says Mr. THOMPSON, have a natural varnish which cotton does not possess. To supply this defect, the repeated immersions, followed by exposure to the atmosphere and to the heated air of a stove, may give the oil the proper consistency, by the absorption of oxygen, for forming a varnish, with which the coloring matter unites, and through which it may be said to shine, which causes that superior brilliancy which the goods attain when they are cleared, or, as it may be called, polished. He therefore presumes that the fixedness and brilliancy of the color will depend on the quantity of oil imbibed, as every repetition of drying presents new fibres to be varnished with an additional quantity; for he has always found that the permanency was in proportion to the number of manipulations in the saponaceous liquor, and a proportionable freedom could also be used in reducing or clearing. The white immersions, omitting the sheep's dung, are just applying successive coats of varnish. Clearing is never attempted from the madder copper, without immersing the goods again in soda and oil, and drying them in a stove, which is considered to be also supplying them with an additional coat.

The alkaline lie occasions a greater separation in the particles of the oil, by which it combines more closely with the fabric of the cloth. The sheep's dung in the first immersions may serve as a covering or great-coat, to keep the goods moist for a considerable time, that they may more fully imbibe the liquor, by preventing the evaporation from being too quick in the great heat to which they are exposed.

After the frequent immersions the cloth feels like leather, no doubt from a superfluity of liquor. It is then steeped in a lie of carbonate of soda, and afterwards well washed and dried, as a preparation for the galling and aluming. The astringent principle has been long known for darkening and fixing common red colors on cotton, by uniting with the earth of alum, and strengthening the basis. To the use of blood in the madder copper, Mr. THOMPSON attributes nothing; as in the rancid and putrid state in which he has seen it employed, were it not for the prejudice of the operator, it might be safely dispensed with.

In proof of the above idea, that it is only the oil uniting with the earth of alum that is of use, he refers to the mode of dyeing that color in the East, quoted by Dr. BANCROFT, namely, soaking their cotton in oil — no matter of what description — during the night, and exposing it to the sun and air during the day, for seven successive days, rinsing it only in running water, and then immersing it in a decoction of galls and the leaves of sumach previous to aluming.

Mr. THOMPSON, therefore, requests the practical dyer, who wishes to arrive at a knowledge of this unaccountable process, to give up the idea of animalization, if by it be meant impregnating the cloth with an animal matter, and by the power of the microscope, or any better method, look for the whole truth from some other source than chemical analysis. He is inclined to believe that it is a mechanical operation united to a chemical, and that the frequent immersions in the imperfect soap are equivalent to laying on the first, second, third, *et cetera*, coats preparatory to finishing a fine painting in oil.

CALICO-PRINTING.—*Impression d'Indiennes*, French; *Zeugdruckerei*, German.—This is, perhaps, the most important branch of industry springing from the parent stem of the cotton trade, and may be described as the art by which topical colors are impressed on cotton cloth, giving variations of form, and gradations of tint, far more cheaply and expeditiously than in the loom. Of late years, silk and woollen fabrics have been made the subjects of a similar style of dyeing, and linens were formerly stained to a greater extent than at present, with various colored designs. Cotton or calico, however, has always been the chief material employed in this department, though the common import of the term Calico-Printer, in the present day, is a printer of all sorts of fabrics—calicoes, muslins, linens, silks, or woollens, or the many mixed varieties, composed of different materials.

Cotton cloth, says BAINES, in his admirable History of the Cotton Manufacture, when used for under garments, is generally worn in the white state; but when used for the outer garments of the female sex, the drapery of beds and windows, the coverings of furniture, and similar purposes, it is ornamented with colors and patterns. Unlike silk and woollen fabrics, cottons are very rarely dyed of a uniform hue throughout; a variety of colors is fixed upon a single piece, and they are printed on the white cotton or muslin in an endless variety of patterns, thus giving a light and elegant effect to the print. The art of the calico-printer, therefore, not only comprehends that of the *dyer*, which requires all the aid of chemical science, but also that of the *artist*, for the designing of tasteful and elegant patterns, that of the *engraver*, for transferring those patterns to the metal used to impress them on the cloth, and that of the *mechanician*, for the various mechanical processes of engraving and printing. *Taste*, *chemistry*, and *mechanics* have been called the three legs of calico-printing.

HISTORICAL NOTICE.—The leading events in the history of calico-printing, considered as a branch of the general art of dyeing, have been given at pages 567 and 568; but its vast importance, its rapid progress, and its intimate connection with recent chemical discoveries, will justify some further details. It has been shown that the art was of very ancient date in India, and that it derived its name from the fact, that the first material printed upon in this country was the East Indian cotton fabric, commonly known as calico. It has been seen, also, from PLINY'S testimony, that the Egyptians appear to have been conversant at a remote period with some of its most refined processes. In different parts of the East, great varieties prevail in the knowledge and skill with which this art is practised. Block-printing is wholly unknown in some parts; and BANCROFT remarks, that in India the patterns are usually, if not always, drawn with a pencil or reed, as may be inferred from the fact, that no two forms or figures in the work are exactly alike; but Mr. BUCKINGHAM states, that at Orfah, in Mesopotamia, the printers have small wooden blocks, of four to six inches square, and use them nearly in the same way as the block-printers in this country. It is well known that the Chinese employed block-printing long before any species of printing was known in Europe. The means and processes by which the art is practised in Asia Minor, Turkey, and, indeed, in all the countries of the East, clearly prove its oriental origin.

It is doubtful in what country of Europe the art of calico-printing was first introduced; but it has been previously stated, that, towards the close of the seventeenth century, Augsburg was famous for its printed linens and cottons, and therefore it must have been practised there long before its introduction into England. It is mentioned in ANDERSON'S History of Commerce, that calico-printing commenced in London in 1676. On the other hand, Mr. JAMES THOMSON, a distinguished and scientific calico-printer, near Clitheroe, stated in his evidence before a select committee of the House of Commons, in 1833, that the origin of printing in England dated from about the year 1690, when a small print ground was established on the banks of the Thames, at Richmond, by a Frenchman, who, in all probability, was a refugee, after the revocation of the edict of Nantz. Its subsequent curious legislative history has been already given. There are, however, some additional facts connected with its early progress which deserve to be noticed, and which have been admirably stated in a lecture read before the Society of Arts, in 1852, by Mr. EDMUND POTTER, reporter to the Jury on Printed Fabrics in the Great Exhibition of 1851. Of these, as well as the important statistical details which his professional and official position afforded him peculiar means of obtaining, Mr. POTTER has kindly authorized the Editor to make free use; and therefore, for much of the substance of what follows with reference to the history and statistics of calico-printing, he begs to acknowledge his great obligations to that gentleman.

The art was first practised in Scotland in 1738, twenty-six years previous to its introduction into Lancashire. Garments only were printed there till 1754. The cloths were made in Scotland, and are spoken of as being made of linen yarns for warps, and cotton for wefts.

It was first established in Lancashire, in 1764, by the Messrs. CLAYTON of Bamber Bridge, near Preston. So anxious were the printers, a few years afterwards, to obviate the difficulty they then experienced in obtaining the cloth, that some of them actually left the more distant districts in which they were living, and even planted themselves where one of the main requisites for their trade—water, was afforded in a very limited supply. The cloth at this time was a calico made of linen warp, crossed with a cotton weft, and was called the Blackburn Grey. A circle of a few miles around Blackburn, long afterwards remained the great seat of the print trade, and that district has, even to the present time, retained a considerable portion of it. Another change in the mode of producing the cloth, tended, however, in no small degree to spread the trade over a wider district; namely, the introduction of the power-loom, which has now completely superseded —except it may be in the extremely low and light fabrics, to a very small extent—the hand-loom weaving, and which, in its infancy, the manufacturers of the Blackburn district dared not introduce, for fear of outrage by the workmen. It was brought into successful operation in Stockport and that neighborhood, and more particularly by the ASHTONS of Hyde, a name intimately associated by its talent, energy, and wealth, with the rising importance of the power-loom calico manufacturing trade, from the commencement of the present century. The best and largest quantity of power-loom printing cloth was first manufactured in Hyde, Stalybridge, and their immediate neighborhood, North Derbyshire. Print-works were afterwards erected in these localities, as they had been somewhat previously, on many of the streams in the immediate vicinity of Manchester.

To return to the period of the introduction of the print trade into Lancashire. The CLAYTONS were followed with greater vigor by Mr. ROBERT PEEL, the father of the first baronet, and grandfather of the late prime minister of this country. Mr. PEEL was a yeoman, and lived at Cross, near Blackburn. Active and energetic, he entered into the cotton manufacture, and added to it the printing business. It is stated by BAINES that he had it from one of his family, that the first experiments were secretly made in his own house, the cloth for printing—in those days by block only—being smoothed for the purpose by ironing. The pattern was one of nature's own—the parsley leaf. He carried on the business for some years afterwards at Brookside, near Blackburn, aided by his sons, and the concern was eminently prosperous. His eldest son, afterwards the first baronet, possessed strong talents, and devoted himself to business from an early age. This son branched off from his father's concern, and established himself at Bury, with his uncle, Mr. HAWORTH, and his future father-in-law, Mr. WILLIAM YATES, names now extinct in the trade, and only remembered as the sharers of the success of the PEEL family. PEEL was to calico-printing what ARKWRIGHT was to spinning: a man of iron mind and frame, possessing what seems to have been very rare among the early printers, great mercantile talent and application, amidst all the shocks of trade, which though then amazingly profitable, carried with it corresponding risks.

Mr. POTTER say he is acquainted with few records of taste of any kind amongst the Lancashire printers of those days. It was not so much needed, their energy and capital being the rather actively employed in branching widely out, and securing the best and newest modes of production. Of the rising men at the head of the various establishments, not a few received their early training from the PEELS, and had been selected by them to fill responsible situations, from which, in the natural course of events, they stepped, to be themselves the heads of future houses.

In 1771 and 1772 the Scottish trade more firmly established itself; and from that time seems to have adapted itself almost entirely to printing handkerchiefs and shawls for the English markets. Special notice is made of the supply wanted for Virginia, Maryland, and the West Indies. The trade of Glasgow, till within a comparatively recent period, was confined to shawls and handkerchiefs. It now produces other classes of work upon a par with those of Manchester, though much less in extent.

Calico-printing at one time was carried on so far north as Aberdeen, but the Editor has reason to believe it is now extinct there.

The production of Great Britain, which, in 1750, was supposed to be fifty thousand pieces per annum, had in 1796 risen to one million, and in 1830 to nearly eight million six hundred thousand—a progress of astounding rapidity, unequalled perhaps by anything but the history of the cotton trade itself.

The most important cause of this increase was doubtless the cylinder printing machine, which, like the steam engine of WATT, came almost perfect into use very early after its first erection in 1785. Some of the machines made shortly after that period were at work in the trade till within a few years past, and were capable of producing single colors with as much precision as any of the more modern ones.

Allusion has been made to the PEELS, as being—as far as Lancashire was concerned—almost the monopolists of the print trade of the last century. During the period 1796 to 1821, the FORTS, HARGREAVES, and THOMSONS, fairly established themselves as extensive and wealthy printers, not more by their energy and business talents, than by their scientific attainments, and by the unbounded and lavish support which they gave to everything which art and science could suggest to assist them.

To show the progress of the trade from 1796 to 1821, it may be sufficient to state that in the former year the quantity produced was one million pieces; in the latter, seven millions. Here it seemed to pause, and as a branch of the cotton trade, for the first time, to make little progress; this, too, with all the capital and energy of the numerous houses then embarked and well established in the trade. The solution of the difficulty soon made itself apparent, but was not so easy of removal. The trade was heavily taxed, and was the only one producing a textile fabric that was so. The cheaper other cotton fabrics of great variety were produced, the more onerous became the tax upon printed cottons. The most remarkable fact was, that the cheaper the printer obtained his cloth, the greater the per centage of taxation he paid. At first, when his material and produce were both high priced—the duty being threepence halfpenny the square yard—the tax amounted to perhaps 2½ per cent., but when it was repealed, and cloth had been cheapened, it had risen to probably 50 per cent. This acted as a bonus for the production of all other kinds of textile fabrics, in preference to printed cottons: nay, even printed silks were free, as were goods printed on the thread before weaving, producing the beautiful chéné effect, so freely used even now in silks, carpets, *et cetera*, and some descriptions of woven cotton goods. The duty had been regularly remitted on exported prints, and *that* portion of the trade shows a small increase in the ten years previous to 1831. For the five years preceding the repeal of the duty, there had been a positive decrease in the home consumption of prints, to the extent of nearly 15 per cent., —this, too, concurrently with an increasing demand for all other classes of textile fabrics.

The printers struggled hard for the removal of a tax in itself so unjust and impolitic, and which was evidently pressing very heavily upon their trade; but it was not till the spring of 1831 that they could obtain its removal. It was, however, one of the first beneficial remissions of taxation made by Earl GREY's government.

The removal of a duty, amounting on an average to 50 per cent. on goods produced for home consumption, naturally gave an immediate impulse, not merely by the reduction in the cost, but by the removal of the harassing and vexatious supervision, under which all trades suffering from excise duties must unavoidably be placed. Various statements were made at the time, as to the additional cost of production, which these restrictions entailed on the printer, and an experience of a quarter of a century has clearly proved that all the statements then made were even below the truth. Thus then the cost was lessened on 6,300,000 pieces exported, as well as on the 2,300,000 retained for home use. Great vitality was at once shown in the trade, and though the records of the excise are wanting since that period, and no public statistical accounts are kept, there is reason to believe that the trade which in 1830 produced 8,300,000 pieces per annum, now yields about twenty millions. Great changes in material, taste, and style, have necessarily been attendant upon so rapid an increase.

First, very great improvements have been made in the material printed on. The regularity of make, and evenness of fabric, in calicoes made by the power-loom, in all qualities, down to the cheapest possible production, gives the English printer a fabric for printing upon, which places him decidedly above the competition of the whole world, in this most essential part of his trade.

The increased demand for quantity led to great changes:—cheapness, the essential element, was attended to,—the machinery improved and quickened. The machines which had hitherto rarely placed on the cloth more than one or two, or perhaps three colors, were enlarged, and made to impress an additional number. Machines are now working producing fifteen or even twenty colors at once, with the same beautiful accuracy and precision as in the case of the smaller number; at the same time yielding six or seven hundred times as many pieces per day, as if blocked separately.

These changes, the perfection of machinery, the quickness of production, and its cheapness, have nearly superseded the slower process of block-printing, and this employment, like that of the hand-loom weaver, must decrease and disappear, except on finer fabrics of slight texture, on which machinery has not been brought to bear; chiefly, perhaps, from the small quantity not affording repayment for the outlay.

The changes in the trade during this period, led to the encouragement of a taste, not so showy as the chintz-block productions—for a long time the highest style in the trade—but of goods of a more elegant and quiet character.

It is but simple justice to acknowledge that at this date the English printer drew largely upon the style of his French competitors. The printers of the then called Swiss prints—really French goods produced in Alsace—were unrivalled in their pink and purple plate work. These goods, even for years afterwards, were imitated successfully, only by a few of the first-class English printers. The progress of the trade in scientific knowledge, now so patent to all, has enabled almost every printer in England and Scotland to produce, with more or less success, this class of goods, varying of course in excellence; in pinks, fully as good, when on an equal fabric, and in purples certainly surpassing those of Alsace. These goods, which were exported by the French, and met with in almost every capital city in the world, are now nearly superseded by the English plate, and to them has been added the supply of a new and increased variety of lower priced prints of a similar class. It is an interesting and curious fact, that the taste in almost every market has changed and improved with the introduction of these goods.

The English printer has also drawn largely upon his French competitor, during the same period, for another trade, which he has likewise, by the aid of the manufacturer and his machinery, done much to make his own. France has long been famous for her beautiful fabrics in fine wool, wool and silk challis, and de-laines, Expensive and costly, made of the finest wool, requiring the greatest care in execution, these goods have been produced with a taste in coloring and design worthy of the beauty and elegance of the material. With them France supplied and led the taste of all the civillized markets of the world. An article so costly was naturally limited in demand. The capital and machinery of the English printer have been brought to bear on this branch of the business. Cotton has been introduced into the fabric, and a beautiful substitute at a low price now occupies the place of the more costly all-wool material of our neighbours. The desired cheapness and beauty have been obtained. Block-printing on this material—the English wool and cotton-de-laine—was for some time the only mode of printing. Machinery has been adapted to it, and the English printer now introduces the cheap article at a low price in every known market, and creates a separate demand which the high-priced one would never have known. The cheaper article has introduced with it no corresponding reduction in quality of the design; quite the contrary; the wider demand for good taste, and the greater power of execution obtained by machinery, have led to new styles of great novelty.

The London printers, up to the repeal of the duty, still held their position for first-class goods. They made great use of the flat-press printing machine—cylinder printing having been but little used in the district. Indeed Mr. POTTER says, he was informed that the first cylinder machine was only introduced in 1812, twenty-seven years after its introduction in Lancashire. Their plates were well engraved, and for a long time they succeeded in getting a smartness of impression better than any at that time obtained from the cylinder. Some few of the Lancashire printers adopted the press, the better to compete with the London printer.

The rapidly increasing trade in Lancashire, and with it the power of so much cheaper production, gradually undermined the London printers, and brought about a complete change in their class of work. Their fine muslin trade for garments has been transferred to the Lancashire and Scotch printers. The London printer has availed himself of his greater advantages for block-work, and has applied himself to printing shawls, waistcoatings, and a variety of fancy handkerchiefs. Silk handkerchief printing has there its chief and almost entire seat for the supply of the whole world, and produces all the variety and excellence of pattern suited to its varied demand. London-printed shawls, the production of Mr. SWAISLAND of Crayford, were shown in the Exhibition; correct in taste, elaborate and beautiful in execution, and fairly equal to anything of the class produced in the French market.

It must be stated that the Lancashire printers, to a great extent, not only contended with the London printers in price, but availed themselves pretty freely of their taste. London patterns were produced at great cost, and their school of drawers was good. Their production being slow and careful, enabled the Lancashire printer by his machinery to fill the markets rapidly with his imitations and copies, to the very serious injury of the London printer. Better taste, and better morals, too, it is to be hoped, now prevail. The Printers' Copyright Bill, which at that period gave protection only for three months' duration, was in 1842 extended to nine months.

The London print trade is believed to be decreasing, and those who are best qualified to form an opinion on the subject think it will continue to do so. Peculiar branches of it will linger last, retained by the talent which often holds out for its generation, but is not renewed. The tendency of the trade is decidedly to concentrate itself; the market will not bear dividing. Thus the Scotch printers are found opening their establishments in Manchester, and transferring the larger part of their mercantile business there. And a new feature has just presented itself in the opening of an establishment there by a French print house of the highest standing.

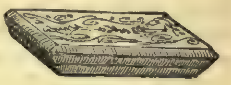
Having brought the history of the art of calico-printing down to the present period, for which the Editor repeats that he is almost entirely indebted to the valuable lecture of Mr. EDMUND POTTER, he reserves for the concluding part of the article the important statistics illustrative of its present condition in this and other countries, which are given by the same high authority, and which can perhaps be obtained from no other source.

PRINTING APPARATUS.—There are four methods of printing figures or designs on calicoes; the first is by small wooden blocks, on which the pattern is cut or otherwise produced in relief; the second by larger wooden blocks, also in relief, and placed in either two or three planes, standing at right angles to each other; the third by flat copper plates, engraved and applied as in ordinary copper-plate engraving, but now little used; and the fourth by a system of copper cylinders, engraved like the plates in intaglio, and mounted on a frame, in which they receive a rotatory movement by steam or water power.

Block-printing by hand.—Previously to the year 1785, hand-block printing, aided by the flat copper-plate printing press, was the only mode of calico-printing. It is impossible to assign the period when the use of the engraved wooden block first superseded the oriental method of literally painting the cloth; but the Greeks are known to have printed with blocks cut in relief before the taking of Constantinople. Though this method be now in great measure superseded by cylinder-printing, yet, as it is still continued for certain parts of the work, some account of the method of block-printing will be necessary.

The hand-block—Fig. 352—is made of sycamore, holly, or peartree wood, backed with deal, and furnished with a strong handle of box-wood. It varies in size from 9 to 10 inches long, and from 4 to 7 inches broad. About the year 1802, an important improvement was made in the construction of the blocks, for which the art is indebted to the workmen of London. Previously, the patterns were cut out in the wood, like ordinary woodcuts used in the prints of books, but the work was necessarily coarser, to endure the wear and tear of so many impressions, amounting, as formerly stated, to 448 applications of the block for each piece of cloth, and therefore requiring for 100 pieces not less than 44,800 impressions. If the design, therefore, was fine and elaborate, the block was soon worn away. The improvement effected removed this objection, and was very generally adopted. The pattern, instead of being cut in relief in the wood, was raised on the surface of a plain block, by pieces of flat copper or brass wire, of various thicknesses and forms, produced by drawing the wire through dies of different thicknesses and shapes. These pieces of wire are forced into the wood by the taps of a hammer at the traced lines of the configuration; the upper surfaces are then filed flat, and polished into one horizontal plane, for the sake of equality of impression, presenting a surface which stands out from the wood about the eighth of an inch. The thicker parts of the pattern have merely the outline formed of copper, and are filled up with felt. As the slips are of equal thickness in their whole depth, the lines of the figure, however much they get worn by use, are always equally broad as at first, an advantage which does not belong to wood-cutting; and hence blocks on this construction are tenfold more durable than the old ones entirely of wood. Sometimes a delicate part of the design is made by the wood-cutter, and the rest by the insertion of copper slips.

Fig. 352.

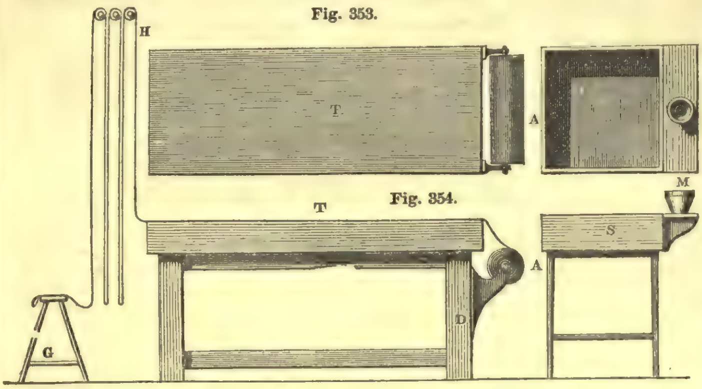


Latterly, stereotyping has been applied to the production of printing blocks. To make the stereotype plate, a model is first formed from the pattern, about five or six inches in length, and from an inch and a half to five inches in width, according to the design. A mould is taken from the model, and from the mould, fixed in a block, copies are produced in the common stereotype metal—see ANTIMONY, page 205. When a number of these pieces are prepared, their surfaces are filed down, and they are then joined together, and mounted on a stout piece of wood to form a printing block.

The block-printing is performed in an oblong apartment, termed the printing shop, lighted with numerous windows at each side, and having a solid table opposite to each window. The engravings on next page—Figs. 353 and 354—exhibit the table with its accessories in plan and section. The table, T, is formed of a strong plank of hardwood, mahogany, or marble, with a surface planed quite true. It is about six feet in length, two in breadth, and three, four, or five inches thick. It stands on strong feet, with its surface about a yard from the floor. It is covered with either one or two blankets, carefully stretched, and fixed down at the corners. At one end of the table the legs, D, carry brackets for supporting the journals of the roller, A, from which the calico to be printed is unwound as the work proceeds, and passing along the table is carried successively over the hanging rollers, H, from which, as it descends, it is piled upon the stool, G. The rollers, H, are fixed as high as possible, sometimes in the apartment above, to facilitate the exposure and consequently the drying of the printed goods, and to prevent one figure being daubed by another.

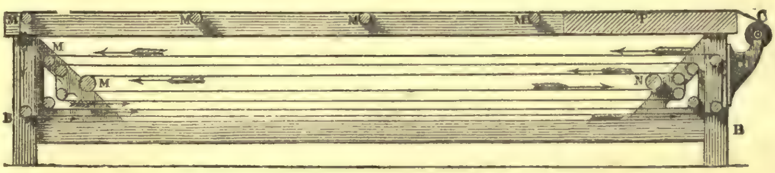
Fig. 353.

Fig. 354.



Sometimes, to avoid the necessity of passing the printed surface of the cloth over a roller immediately after leaving the table, the arrangement represented in Fig. 355 is adopted, where the stuff, passing from the roller, C, over the printing-table, T, continues its course over the rollers, M, M, M, M, from which it proceeds under the table round the rollers, B, B, and over the additional rollers, M, M, in constantly narrowing circumvolutions, as shown by the arrows, until it is finally wound upon the bobbin, N. By this arrangement the printed surface of the cloth does not come into contact with any of the rollers. The extreme bobbins, C, N, are fitted with winch handles to move the cloth forward, after printing a portion equal to the length of the table.

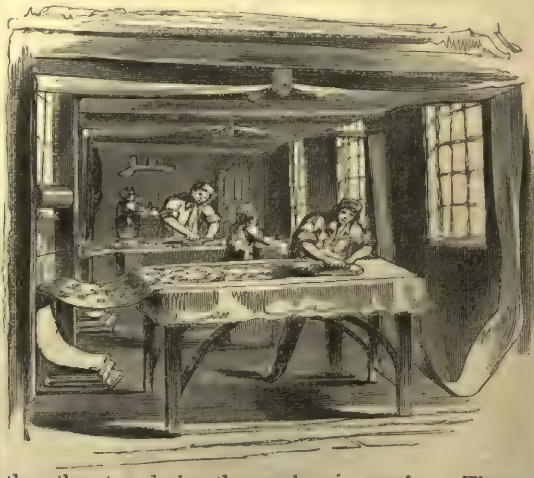
Fig. 355.



The workman charges the block with color by pressing it upon a surface of woollen cloth stretched tightly over a wooden drum, which is called the *sieve*, and is made to float in a tub of size or thick varnish, S—Fig. 354—for the purpose of giving it elasticity; M is the pot containing the supply of thickened color for the day's work. The inverted sieve or drum should fit the paste-tub pretty closely. The sieve is covered with the coloring matter by a child, called the *tearer*—probably from the French *tireur*—who takes up with the brush a small quantity of color from the pot, and spreads it uniformly over the surface of the sieve; and every time that the man presses his block upon the sieve in order to charge it with color, it is the duty of the tearer to brush over the woollen surface, in order to erase the mark of the block, that the latter may be evenly charged with color at the next operation.

It may here be stated that before proceeding to print the calico, it has to undergo the preparatory operations of singeing, bleaching, and calendering. The singeing is performed by drawing the cloth rapidly over a convex surface of sheet-iron raised to a red heat. By the rapidity of the motion, the cloth is not burned; but the loose down is effectually burned or singed off. By another method the cloth is drawn rapidly over an elongated gas flame. The processes of bleaching and calendering—see page 317—have been already described, and that of singeing will be more fully explained afterwards. Having passed through these operations, the cloth is ready for the printing; and a number of pieces, stitched end to end, are lapped round the roller at the end of the table. The printer unfolds a length of the piece upon this table, taking care to place the selvage toward himself, and one inch from the edge. He presents the block towards the end, to determine the width of its impression, and this width he marks along the piece on the table by drawing a line with his tracing point. The spreader or tearer now besmears the sieve with the color; the printer seizes the block with his right hand, and daubs it twice in different directions upon the sieve cloth; then he transfers it to the calico within the line marked, and generally strikes it on the back with a wooden mallet, in order to transfer the impression fully. Having done so, he again charges the block from the sieve; and to enable him to make the next impression exactly join or fit in with the last, the block is furnished with small pins at the corners, two of which he inserts in the marks that were made by the other two during the previous impression. Thus, by repeated applications of the block, a pattern is produced in one color. The accompanying engraving

Fig. 356.

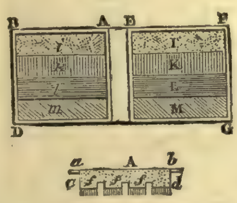


shows the block-printing process in operation, with the general character of the arrangements.

Printing different colors with one block.—If the pattern contain five or more colors, there must in general be as many blocks as there are colors, all of equal size, the raised portions in one, which take up color, corresponding with the depressed portions in the others, which do not. In order, therefore, to print a piece of cloth twenty-eight yards long and thirty inches broad, no less than 672 applications of a block, nine inches long and five inches broad, are requisite for each color; so that if there are only three colors, no less than 2016 applications will be necessary. But if the design consist of parallel stripes of different colors, they may be applied by one block at a single impression, and the block is also charged with the different colors by a single application to the sieve or surface of woollen cloth. The colors to be applied are contained in separate small tin troughs arranged in a line. A little of each color is transferred from the tin troughs to the sieve by a kind of wire brush, consisting of wires fixed in a narrow piece of wood, and the colors are distributed evenly in stripes over the surface of the sieve by a wooden roller or rubber covered with fine woollen cloth. In those patterns in which the colors merge into one another at the edges, constituting what is called the *rainbow style*, they are first blended by a brush on the sieve before being taken up by the block.

Considerable improvements have been effected upon this method, of printing simultaneously different colors with one block. The arrangement first adopted was that shown in Fig. 357, where E, F, G, H is a box or tray of tinned copper or iron, divided into a series of compartments for holding the different colors by partitions, I, K, L, M. A is a brush of equal length with the color-box, measured across the compartments, and divided into sections, *f f f*, with openings corresponding to the partitions, so as to constitute in fact a series of pencils. This brush the tearer dipped into the box to the depth of *c d*, and, in taking it out, pressed it against one of the sides to discharge the excess of color, and then moved it backward and forward on the sieve, A, B, D, C, depositing thereon belts of color, *i*, *k*, *l*, *m*, corresponding to the colors I, K, L, M in the box. To prevent him from pressing too much on the sieve, so as to produce a confusion of shades, the brush was made to rest on the sides of the sieve by projections, *a*, *b*.

Fig. 357.



But as this arrangement did not allow of depositing many tints on a limited space, since the different divisions of the brush required to be always at a certain distance from each other to prevent intermixture, the brush was laid aside, and the following method is generally practised at the present day:—

A—Fig. 358—is a box for holding the different colors, divided by partitions, C C, into as many compartments as are required. Till lately, these troughs were formed of tinned iron or copper, but latterly they have been constructed of wood or plaster, with slips of glass for the partitions. Fig. 359 is a piece of wood, on which are fixed, and drawn tight like the strings of a violin, copper-wires, *f f*, or hempen, cotton, or woollen cords. When formed of wire, the latter must be selected of a thickness corresponding to the quantity of color required to be deposited on any given point; it is then bent at right angles, and nailed to the sides of the piece of wood, as shown in the figure. When strings or cords are used, they are stretched between slips of copper, all of equal length, fastened to the sides of the board. Strings of different thicknesses may be selected, from a stout cord to a slender thread or filament, according to the breadth of the stripe of color to be laid on. Narrow ribands of copper, of different widths, have likewise been substituted for the wires or strings. The tearer applies the colors to the sieve by taking hold of the board, B, dipping the wires or strings into the compartments of the box, A, to which they are made to correspond in number, and then applying them to the sieve.

Fig. 358

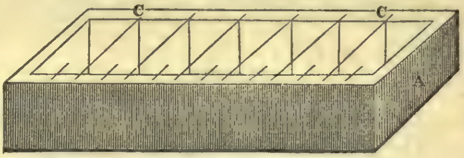
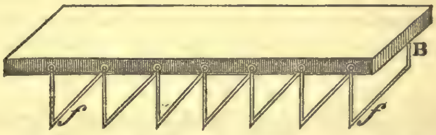
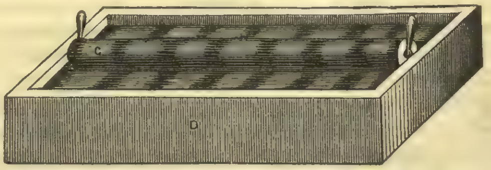


Fig. 359.



The lines or stripes of color thus deposited may then be spread by a brush; but a roller is better for this purpose, as shown in Fig. 360, where D is the trough containing the paste or mucilage on which the sieve rests, and G is a roller, fitting it exactly in length, and furnished with handles, by which the tearer moves it backward and forward lengthwise over the parallel stripes. The roller is thus prevented from deviating to either side; and when the colors are numerous, slits or grooves may be cut round it corresponding to the intervals between the colors or their points of junction, so as effectually to prevent their mixing together. By varying the thicknesses of the wires or strings, and by increasing them in number and contiguity to any extent, a great variety of striped patterns may be produced in this manner.

Fig. 360.



Further, the pattern may be made with curved lines of any form by a very simple arrangement, shown in the annexed cuts—Figs. 361 and 362. In this case the partitions of the box, A, are made of some flexible material, such as pasteboard, varnished over with any bituminous substance, and bent into any required shape; and the wires or metallic slips of the block, B, are made to correspond. When the colors deposited in this manner are spread with the brush, the effect is shown in Fig. 363, where D is the trough containing the sieve, and *f* the brush. It will be observed that the sides of the trough on which the ends of the brush rest are fashioned into corresponding curves, so as to communicate an oscillating movement to the brush as it passes over the tinctorial matters, and thus the same part of it always comes into contact with the same color.

Fig. 361.

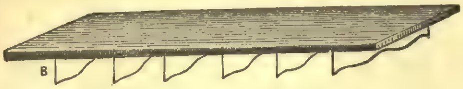
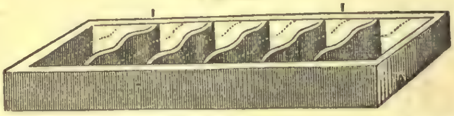
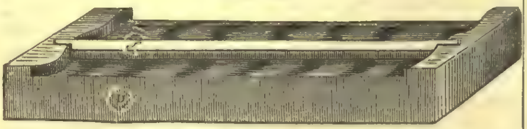


Fig. 362.



The principle of this method admits of numerous applications. Patterns of concentric circles or zones of different colors, and other varieties, may be formed by simply having the color troughs divided into corresponding compartments.

Fig. 363.



Improved Color-holders.—Mechanical details do not properly fall within the province of this work; but in the various processes of calico-printing more mechanical ingenuity is displayed than probably in any other chemical art; and no adequate idea can be formed of its wondrous resources and applications without an intelligent appreciation of the apparatus employed. An article or treatise on the art would indeed be very incomplete and unsatisfactory which did not to some extent enlighten the reader on this subject; and this the Editor is the more disposed to attempt, as he is not aware that there are any works in the English language in which the apparatus used in calico-printing has received justice, either in point of description or illustration.

The truth of these remarks will appear when the methods of cylinder-printing, and block-printing by machinery, are discussed. In the meantime, the Editor will proceed to describe, as briefly as possible, some improvements in the apparatus connected with block-printing by hand.

In the first place, there are some colors—such as certain blues—which cannot be long exposed to the oxygen of the air without injury. To avoid this, the very simple arrangement represented in Fig. 364 has been adopted. A is a small copper vessel, two or three inches in depth, and a little longer in horizontal dimensions than the printing-block. This vessel communicates at its lower part with the color cistern, B, by a tube fitted with a stop-cock, R; and at about half its height is fixed the woollen sieve, T. When the stop-cock is opened, the color from the cistern arrives under the sieve, and tends to press upward through it, with a force proportioned to the height of the column of color in the vessel, B; and the quantity of color which forces itself through the sieve may be nicely regulated by the stop-cock.

It is evident that this arrangement may be adopted with troughs divided into compartments for containing different colors. In that case, each compartment is made to communicate by a tube with its own cistern, as represented in Figs. 365 and 366, the former of which is a plan, and the second a vertical section of the color-troughs and tubes. Suppose, for example, that the pattern to be printed consists of four colors—green, red, yellow, and violet—in that case there are four cisterns or reservoirs, A A A A, forming the sides of the sieve, which is divided into compartments, E E E, according to the shape of the pattern. The cisterns, A, communicate by tubes, B, of lead, caoutchouc, or gutta percha, with the lower surface of the sieves, E, which are separated from each other by leaden or wooden partitions, to prevent the colors from mixing. It is almost needless to state, that the colors must have sufficient fluidity to flow freely through the tubes, as well as to penetrate the meshes or pores of the sieves; and they ought to stand in the cisterns, A, at nearly the same level as the sieves, so that a constant supply may be maintained, sufficient to penetrate the latter without forcing their way in superabundant quantity.

Fig. 364.

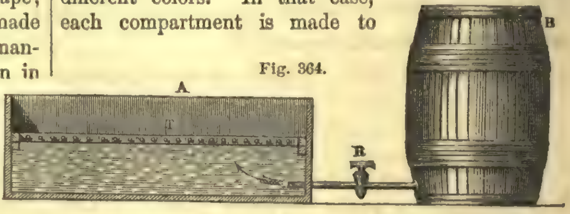


Fig. 365.

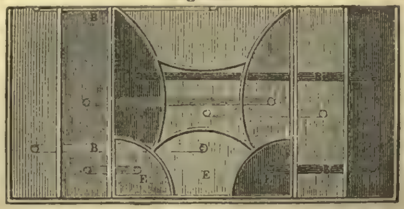
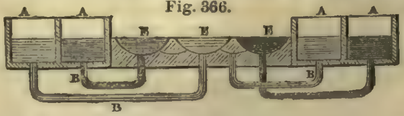
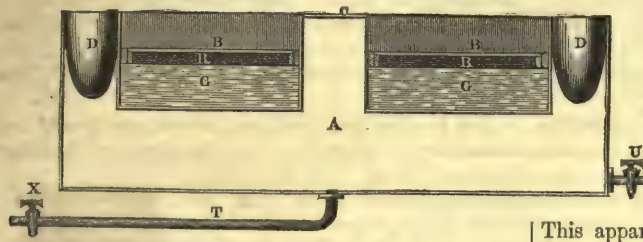


Fig. 366.



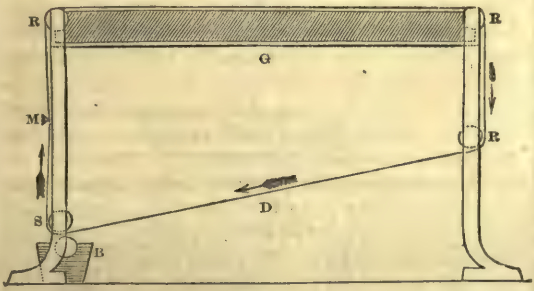
Some colors or mordants require a higher temperature than that of the printing shop to bring them to a state in which they can be best applied to the cloth. In that case, the sieve-trough, with its cistern, may be inserted in a larger vessel filled with water kept at a certain temperature, or heated by steam. An arrangement of this kind is shown in Fig. 367, where B G, B G, are two copper vessels corresponding to A in Fig. 364, each fitted with its sieve, R, for the use of a couple of printing tables. D D are two small basins for holding the color, and which, as well as the sieve-tubs, G G, dip into the steam-chest, A. The tubes, T X, and U, are for admitting and discharging the steam.

Fig. 367.



Mechanical Tearers.—Different arrangements have been invented to dispense with the services of boys for spreading the colors. By one method, the tub or trough containing the mucilaginous cushion, or *false color* as it is called, instead of being covered with a fixed sieve exactly fitted into the trough, is covered, on the contrary, with an endless web, which circulates from the color-pot placed beneath it, as shown in the annexed engraving—Fig. 368—where G is the tinned trough or tray, filled with the paste or false color, and covered hermetically by a waxed cloth, so as to be slightly convex on the surface. Over this surface, and receiving its movement from the cylinder, S, circulates the endless web, D, passing round several rollers, R R R, and charged with color on one of its surfaces by the roller, B, which circulates in the trough containing the color. The superfluous color is thrown back into the trough by the scraper, or *doctor*, M. The printer applies his block to its upper surface over the paste cushion, G.

Fig. 368.



This mechanical tearer, as such contrivances are termed, has several disadvantages. Besides being somewhat expensive in the first construction, and requiring a constant power to keep it in motion, it is not fitted for the transmission of those colors which speedily dry or thicken when exposed to the air.

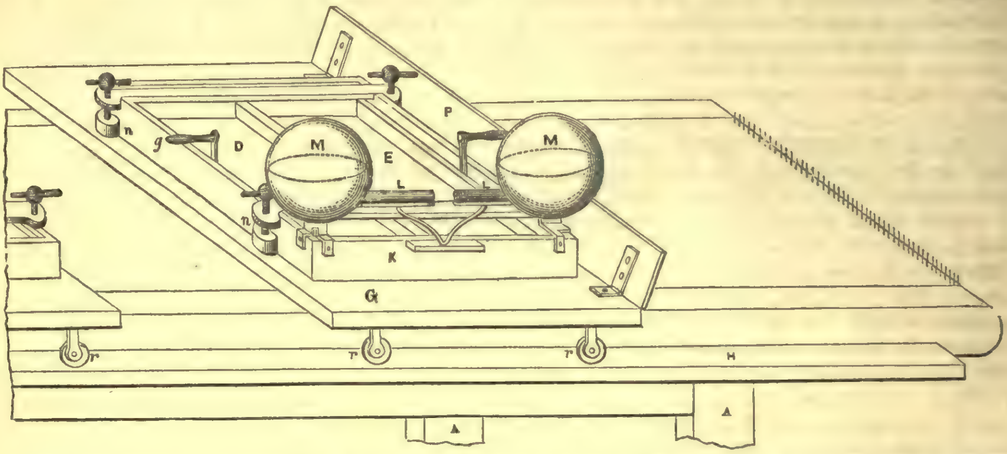
A mechanical tearer, which is not liable to these objections, was invented by M. M. DUPASQUIER of Neuchâtel. It consists of a trough for containing the color, over which the sieve is extended, so that the color itself acts as the mucilaginous cushion. A cross bar, mounted on small wheels, running on rails, which are fixed upon each side of the trough, carries two elastic plates or blades, which press with their edges on the sieve and spread the color. This part of the apparatus is properly the mechanical tearer; and, by a very simple system of pulleys, is connected with a pedal attached to the printing-table; so that the printer, by merely pressing with his foot on the pedal, draws the spreaders over the sieve, and again, on removing the pressure, these are immediately carried back by a counterweight. This apparatus is highly recommended by PERSOZ; but it has also its disadvantages; and, indeed, the attendance of a boy is often useful to the printer to assist him in spreading his cloth and for other purposes.

Movable Color-holders.—Sometimes the printing-tables require to be of great length—from twelve to fifteen yards—to receive, for example, costly fabrics for dresses, which are to be printed and finished in one piece, and to which it is desirable that all the colors composing the design be applied in succession, without changing the position of the cloth during the process. In such cases one can readily conceive the inconvenience of having the color-trough stationary at one end of the long table, not only causing loss of time in passing backwards and forwards to charge the block after each impression, but rendering the colors liable to dry or thicken upon the block before they are applied to the stuff.

To obviate these disadvantages, the whole apparatus connected with the color-trough is sometimes made to run upon rails, fixed upon the sides either of the printing-table itself, or of another table placed parallel to it. The best arrangement of the kind is that recently invented by M. PAUL GODEFROY, and shown in the engravings—Figs. 369, 370, and 371—both in its *ensemble* and in detail. In each of these figures the same letters refer to the same parts.

A A are the feet or supports of a table, similar in construction to the printing-table already described. This table may have any required length, and is furnished on both sides with grooves or rails, H, on which run the castors, *r r*, of the movable stands, G. This last supports the color trough, K, which, yielding to the slightest impulse, advances or recedes at the will of the printer; or, if the style of printing require it, it is moved backwards and forwards by the tearer, who stands on a platform parallel with the table. K is a wooden box, with its joinings accurately fitted together, and having on each of two opposite sides two notches or indentations, *k k*, to receive the cross-pieces, *a a*, fixed to a frame or chase, C. This box, K, may be divided into any number of compartments, by partitions, *f*, as shown in Fig. 371; and the color introduced into this box performs at the same time the part of the paste cushion, the sieve being placed immediately over it to be impregnated with the

Fig. 369.



color. The latter is admitted into the trough or withdrawn from it by the openings, S, S. D, E are simple chases, or sieves, formed of a square wooden frame, with woollen or other stuff stretched over, capable of permitting the color to pass through when a certain pressure is applied. At the two ends of this frame are fixed the cross-bars, *a a*, which, by falling into the notches, *k k*, keep the frame in a fixed position. These cross-bars carry at their extremities wooden screws, *m m*, which turn in wooden nuts, *n*, *n*, fixed to the color-trough; and by means of these screws the printer can elevate or depress the sieve in the color as he finds necessary. The chases, D, E, with compartments, are shown upside down, to exhibit the groove or grooves corresponding to the partition or partitions, *f*, of the trough, K.

To keep the color at a constant level, when the screw has been adjusted in its proper position, matrasses, or globular glass vessels, M M, are fixed at the corners of the side of the trough opposite to that at which the printer works. These matrasses are filled with color and turned upside down in the trough, so that when the color contained in the latter sinks a little, a portion of air rises into the globe, displacing an equal portion of color. These matrasses, therefore, act as color cisterns.

Fig. 370.

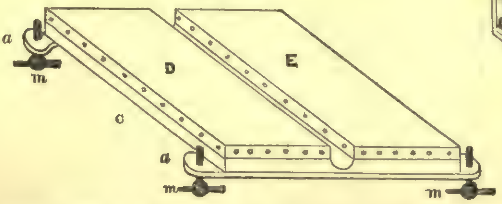
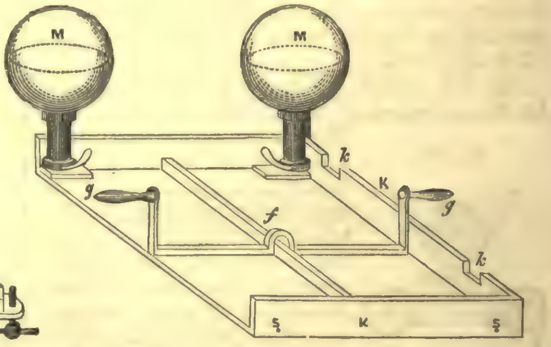


Fig. 371.



As the color requires to be occasionally stirred, each trough is fitted with a bent rod, which is moved by turning the handles, *g*, and thus affords the means of thoroughly mixing the color without raising the sieve-frame. Further, to equalize the color on the surface of the latter, a small roller, L, which may be either single or compound, according to the number of compartments, is passed from time to time over the surface.

Lastly, to the stand, G, is fixed a board, P, in an oblique position, to defend the calico or other fabric in the course of being printed, from drops of color which are apt to fall from the block while the printer is raising it from the sieve.

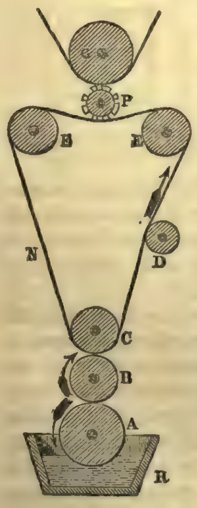
This arrangement may be used for printing a number of colors with the same block, in the manner already described for the rainbow style. It adapts itself to any length or size of table. It seems to be applicable, in short, to any kind of block-printing.

BLOCK-PRINTING BY MACHINERY.—Employing the expression *block-printing* in a somewhat lax sense to signify generally printing by surfaces in relief, the Editor will now consider the methods devised for bringing the precision and rapid execution of mechanical power to bear upon this department of calico-printing. It is true that if the order of time was followed, the method of printing by engraved cylinders of copper, having the design cut into the surface, would now fall to be considered; for this was the mode which first superseded the hand-block in common practice—which first introduced, in short, the general application of mechanical power, as a substitute for manual labor and dexterity in calico-printing. From its vast importance, however, and its almost universal application, cylinder-printing is reserved as the last and principal subject for illustration; while, at the same time, it is only natural to follow up into its latest improvements that method of printing by surfaces engraved in relief, of which the common hand-block is the type.

Surface-Printing.—When cylinder-printing was introduced with so much success, and even before its introduction, it was natural to think of applying the same continuous system to surfaces engraved in relief—to form, in fact, cylindrical blocks, with the figure or pattern standing out from the surface as in the common block, and to obtain from these a continuous series of impressions by mechanical agency. PERSOZ states, that the first machines of this kind appear to have been invented in France, and were termed *plombines.* A person named EBINGER, of St. Denis, near Paris, took a patent for the invention in 1800, hoping to imitate the English printers, who, for several years prior to that period, had worked by a continuous mechanical method, the processes of which were then unknown in France. This mode of printing, which was formerly practised extensively in some establishments, is called *surface-printing,* probably, says URE, because the thickened color is applied to a tense surface of woollen cloth, from which the roller takes it up by revolving in contact with the cloth. The union of a wooden cylinder in relief with an engraved copper cylinder, forms what has been denominated the *union* or *mule machine,* and was the invention of Mr. JAMES BURTON, about the year 1805, when he was an engineer in the establishment of Messrs. PEEL and COMPANY, of Church.

Fig. 372 exhibits the most improved arrangement for the application of the wooden cylinder in relief. The endless web, N, receives the color from the trough, R, by the rollers, A, B, which, by their friction against each other, tend to spread it uniformly, and this is still further accomplished by the roller, D. The endless web was formerly made to pass over only two cylinders, one in the position of C, and the other immediately under the printing cylinder, P. By that arrangement, however, it was found that the cylinder, P, did not sufficiently take on the color, the surface of the cylinder below being also convex. Hence the improvement effected by circulating the woollen cloth, in the upper part of its course, over two cylinders, E, E, placed at the same height; and this cloth, being tightly stretched, yields a kind of bed or cushion for the relief surface of the cylinder, P. The calico to be printed circulates round the roller, G.

Fig. 372.

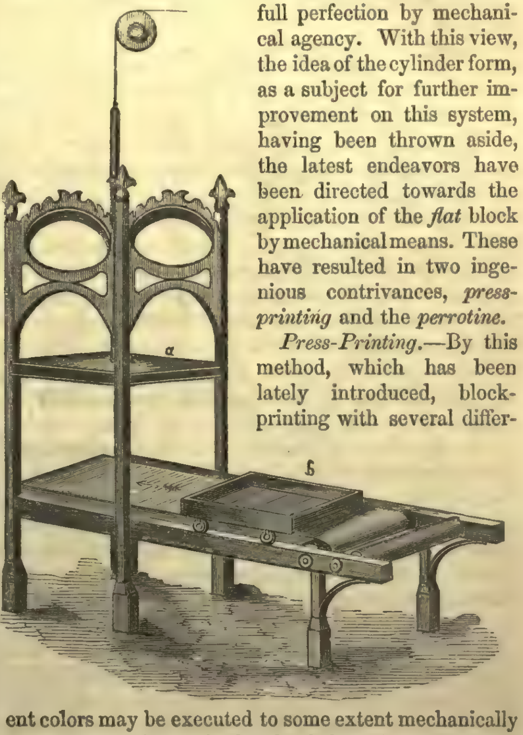


The design may be formed on the cylinder, either in the manner of ordinary blocks for woodcuts, or by inserting slips of copper. This method of printing has one important advantage over the engraved copper cylinder, when two or more different colors are to be applied to the cloth. In this case the portion of the pattern impressed by one copper cylinder is always subjected to the action of the unengraved portion of the other cylinders, which to a certain extent must render it less clear and distinct by spreading it a little upon the stuff, whereas, when the second color is printed with a cylinder in relief, the color that was first printed is left untouched. Hence the advantage of combining the block system with the copper cylinder, as in the union machine. The block, or cylinders constructed on the principle of the block, have also this advantage, that they do not come into contact with the ground of the fabric, which, whether it be a pure white, or any delicate color, must always be more or less stained by the unengraved surface of the copper cylinder, whatever precautions may be taken to remove the superfluous color. Hence, surface printing is still employed with advantage in the union machine, and is more especially useful for producing impressions of white and yellow patterns on blue grounds.

There is, however, one fatal defect connected with this cylindrical block system, which it has hitherto been found impossible to remedy—the color impressed in this way by a curved surface is always more or less spread out, not being kept to the same precise spot as in the lines or hollows of the engraved cylinder; and hence the beauty and regularity of the forms composing the pattern are always more or less impaired.

Still, the important advantages of the block, in coming into contact only with those parts of the cloth intended to receive the color from itself, and neither with the white or colored ground, nor with the other parts of the pattern already printed, have naturally induced a variety of efforts to work it in full perfection by mechanical agency. With this view, the idea of the cylinder form, as a subject for further improvement on this system, having been thrown aside, the latest endeavors have been directed towards the application of the *flat* block by mechanical means. These have resulted in two ingenious contrivances, *press-printing* and the *perrotine.*

Fig. 373.



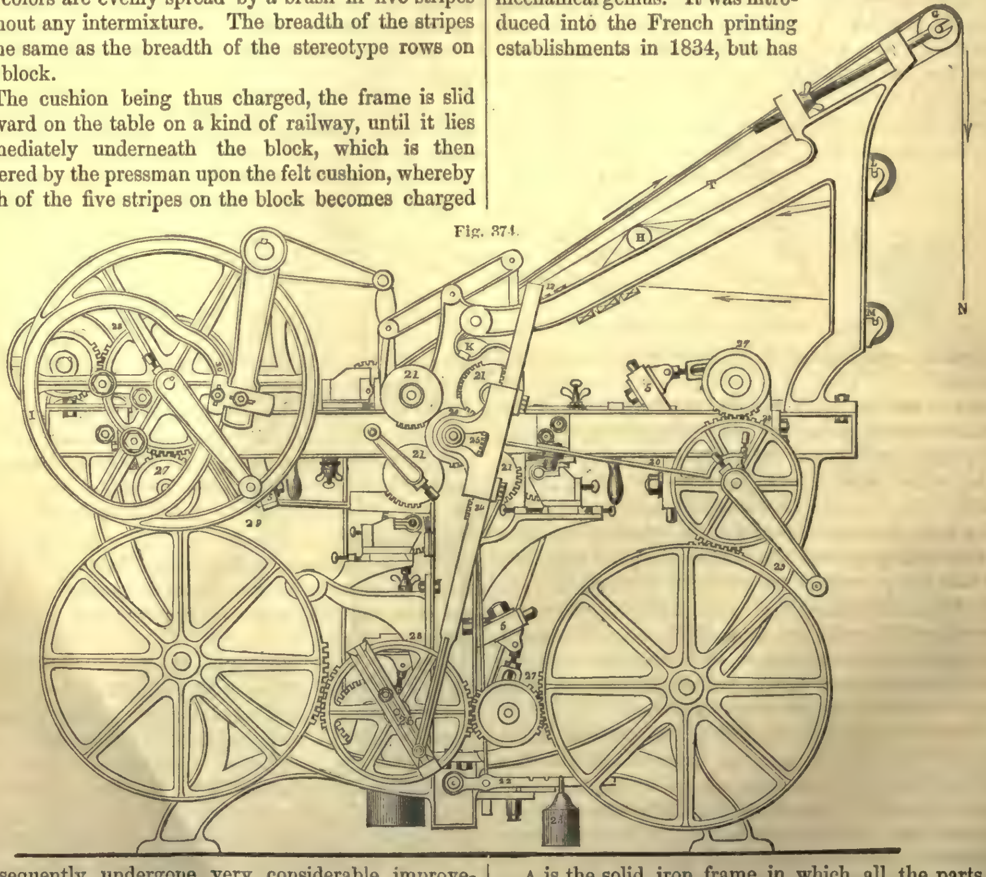
Press-Printing.—By this method, which has been lately introduced, block-printing with several different colors may be executed to some extent mechanically at one impression. A sketch of the principal parts of the machine employed for this purpose is shown in Fig. 373, and its mode of operation is very well described by PARNELL in the following terms:—The block itself, *a*, consists of a well prepared tablet of wood, about two feet six inches square, supported in an iron frame in such a manner that it can be raised or lowered vertically at pleasure. The face of the block is divided into as many stripes—crossways with the table—as there are colors to be printed, which may be supposed, for illustration, to be five. The stripes are about six inches in breadth and as long as the breadth of the cloth to be printed; each one prints a different color, and the whole five form together the combined pattern. The printing surfaces are stereotype casts, made of the mixed metal, antimony, tin, and lead.

The mode of applying the colors to the printing surface is very ingenious. At the bottom of the wooden frame, *b*, near to one end of the table, is a felt cushion about the same size as the entire block, and immediately within one side of the frame are arranged in a line five little troughs—or as many as there are colors to be printed—containing the thickened colors. By means of a long piece of wood, so formed as to dip into all the troughs at once, the attendant tearer applies a little of each of the five colors to the surface of felt, over which the colors are evenly spread by a brush in five stripes without any intermixture. The breadth of the stripes is the same as the breadth of the stereotype rows on the block.

The cushion being thus charged, the frame is slid forward on the table on a kind of railway, until it lies immediately underneath the block, which is then lowered by the pressman upon the felt cushion, whereby each of the five stripes on the block becomes charged with its proper color. This being done, the block is raised, the color-frame withdrawn, and the block caused to descend on the cloth, which it imprints in five rows with different colors. When the block is raised, the cloth is drawn lengthways over the table about six inches, or exactly the width of one stripe on the block: the tearer again slides over the cushion with more color, and the block is again charged and applied to the cloth. As a length of the cloth equal to the width of a stripe is drawn from underneath the block at each impression, every part of the cloth is brought into contact successively with all the stripes on the block. The part printed by the fifth stripe at the first impression becomes printed by the fourth stripe at the second impression, by the third stripe at the third impression, by the second stripe at the fourth impression, and by the first stripe at the fifth impression. When this machine is well managed, its action is very neat; but extreme nicety is required in properly adjusting all the moving parts of the press in order to prevent confusion of the colors and distortion of the pattern.

The Perrotine.—This machine, which is so called in honor of its inventor, M. PERROT of Rouen, is characterized by PERSOZ, without even excepting the steam-engine, as perhaps the most interesting invention of mechanical genius. It was introduced into the French printing establishments in 1834, but has subsequently undergone very considerable improvements. Fig. 374 represents an elevation, and Fig. 375 a vertical section of the perrotine.

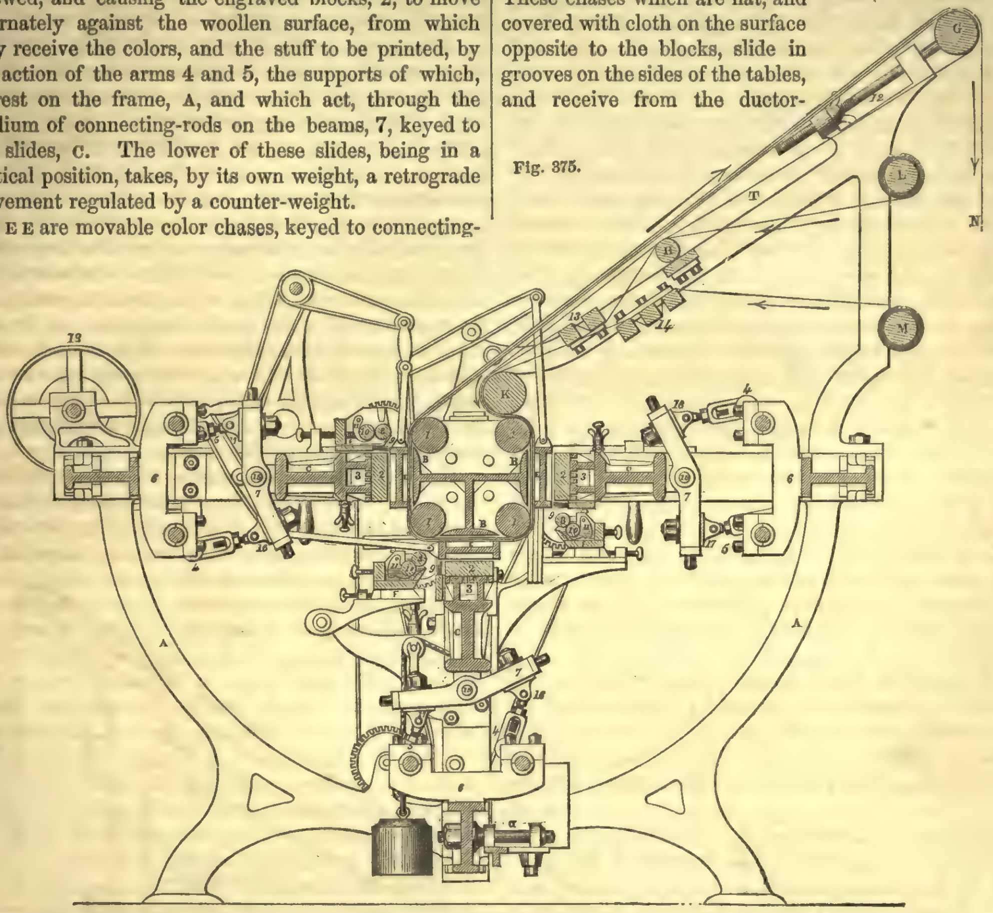
Fig. 374.



A is the solid iron frame in which all the parts of the machine are fixed. B B B, iron tables, dressed perfectly smooth, on which circulate the endless web, the blanket or *doubler*, and lastly, the fabric to be printed; C C C, sliding pieces, to which the block-holders, 3, are screwed, and causing the engraved blocks, 2, to move alternately against the woollen surface, from which they receive the colors, and the stuff to be printed, by the action of the arms 4 and 5, the supports of which, 6, rest on the frame, A, and which act, through the medium of connecting-rods on the beams, 7, keyed to the slides, C. The lower of these slides, being in a vertical position, takes, by its own weight, a retrograde movement regulated by a counter-weight.

E E E are movable color chases, keyed to connecting-rods, and receiving from the power applied to the machine the kind of movement which they require. These chases which are flat, and covered with cloth on the surface opposite to the blocks, slide in grooves on the sides of the tables, and receive from the ductor-rollers the colors which they afterwards transmit to the blocks.

Fig. 375.



F F F are the color troughs, filled with color, and furnished each with two rollers, 8 and 10, the last of which, dipping into the troughs, are charged with color, which they communicate to the rollers, 8, the latter being covered with woollen cloth, and these in their turn transmit their color to the chases, E, on which it is spread by the fixed brushes, 9. As it is important to be able to vary at pleasure the quantity of color supplied to the chases, and consequently to the blocks, the rollers, 10, are in connection with levers, 11, which, by means of adjusting screws, bring them into more or less intimate contact with the rollers, 8, and consequently vary the charge of color at pleasure.

The mechanism for circulating the endless web, the blanket, and the fabric, is as follows:—At the four angles formed by the three tables, B, are rollers, 1, armed on their surface with needle-points, which prevent the cloths from slipping as they pass round, and thus secure the regular movement of the stuff to be printed, a movement determined by the toothed wheels, 21—Fig. 374—fixed at the extremities of the axes of these rollers. G is a roller for stretching the endless web, resting with the two ends of its axes on two cushions forming the extremities of the screws, 12, by which the roller can be pushed further out when required to give the cloth the necessary tension. H is another tension roller, supporting the endless web and the blanket. K is a roller which serves similar purposes for the endless web, the blanket, and the fabric in process of being printed. T, the endless web, which in its course embraces the semi-circumference of the roller, G, passes over the roller, H, and behind K, to circulate round the cylinders, 1, and over the surfaces of the tables, B.

L is a cylinder from which the blanket is unwound, being first stretched by the roller, H, and then drawn out in its breadth by the widening rules, 13, from which it proceeds to join the endless web on arriving at the roller, K. M, a winch from which the calico or other stuff to be printed is unrolled by the movement of the machine passing through the widening rules, 14, to join at K the endless web and the blanket, which it accompanies in their course till it arrives at the roller, G, where it passes off to the hanging rollers in the direction of the line, N.

It now remains to explain the action of the machine.

It is worked either by the hand with a winch-handle, or by power communicated by a strap which passes over the pulley on the left hand, marked 18. This pulley has several diameters to give different speeds; it is loose on the driving shaft, and carries catches by which it communicates its motion to the mechanism when the machine is to be worked.

Directing attention, in the first place, to the movement of the cloth, it will be seen that this movement, like the printing itself, is necessarily intermittent. It must also advance at each step by a distance exactly equal to the breadth of the block, and this advance must be executed during the time that the chases are being charged with color from the ductor-rollers, 8. This result is obtained by means of a dividing-wheel, 20—Fig. 374—connected with corresponding mechanism. The wheels, 21, fixed at the extremities of the axes of the cylinders, 1, and having each the same number of teeth, receive their movement from a central wheel, toothed in the same manner, and placed behind the wheel, 20. This last receives an alternating motion from a rack, 24, fixed in a copper piece, 25, and which rises and falls alternately, being keyed at its lower end to one of the spokes of the wheel, 28. By varying the position of the point at which the end of the rack is connected with the spoke, 26, the length or range of its movement is proportionally changed, and more or less of the teeth of the wheel, 20, are made to pass, which renders proportionally greater or less the advance of the cloth at each movement; and this is further regulated by a ratch-wheel placed at D. At each half-turn of this last, the lever, 22, raises the catch or pallet, and throws out of gear the wheels, 21, during the other half-turn; but as in the working of these wheels, there would inevitably be a backward movement, this is prevented by a break consisting of a pulley mounted on the shaft of the axis of the wheel, 20, and a brass wire, which, after making a turn and a half or two turns on this shaft, is stretched by the weight, 23, which offers a sufficient resistance to any recoil.

The next point to be considered is the action of the slides or block-holders. These are put in motion by the wheels, 27, 28, gearing with the larger wheels, 29. And to vary their action at pleasure, both for causing the blocks to bear more or less strongly on the chases, so as to be more or less charged with color, and likewise for attaining the exact pressure which suits best for the color to be laid on, it is sufficient to move the points of junction, 16 and 17, to a greater or less distance from the point marked 15, which constitutes the centre of oscillation of the beams that work the slides.

The movement of the chases is controlled by that of the cam, I I 30, which works them all three by putting in motion a shaft with which they are respectively keyed.

The ductor-rollers receive their movement from gearing with pinions on the axes of the rollers, 8.

The Editor will now endeavor to explain the general working of this complex machine. When put into regular motion, and the three blocks have delivered their impression exactly at the same instant, three simultaneous movements immediately commence.

1st. The stuff advances by a length exactly equal to the breadth of the block, and with it the endless web and the blanket, so that the portion of the fabric which leaves the third block behind it is fully printed; that which was under the second advances opposite the third; that which was under the first moves along to the second; and a fresh breadth of the white or unprinted fabric arrives opposite the first.

2d. While the cloth is advancing as above stated, the chases take the place which they occupy in the section—Fig. 375—that is to say, the first, on the right hand, rises, the second moves from left to right, the third descends; and in this movement all three press slightly on the ductor-rollers, 8, from which they receive the color, which has been spread uniformly by the brushes, 9.

3d. In the meantime the slides or block-holders, by a forward movement, push the blocks against the chases, to charge them with color, and the blocks at the same time receive from the slides a gentle backward movement, during which the chases deviate from their position; the blocks then return upon them and are drawn back again, after being applied to a new part of the color surface.

When these simultaneous movements have taken place, the action of the machine proceeding without intermission, the chases move back from before the blocks, and these are pushed up against the latter, printing the portion of the fabric which is stretched upon them. This brings the machine to that portion at which the description commenced; and this succession of movements is renewed and repeated as long as the operation lasts, the attendant having it always in his power to suspend the advance of the stuff whilst the working of the blocks and chases continues, so that the color may always be re-applied to the same part of the fabric as often as may be required for a good impression.

In 1844 M. PERROT exhibited a machine for printing four colors, the same in principle as that which has just been explained, but somewhat more difficult of construction. In the perrotine, as now improved, says PERSOZ, the printer finds, along with a much more correct execution of difficult patterns, a great economy of manual labour. Variously-colored patterns are printed by it on pure white grounds with the utmost delicacy of execution; and, as regards saving of labor, two men print in three colors with the perrotine from one thousand to fifteen hundred yards of calico daily—an amount of work which, with the ordinary block, would require twenty-five printers and as many tearers. It may be added that by suitable arrangements, and by employing tearers to distribute the colors in the chases, the perrotine has also been successfully employed in producing the rainbow style. M. PERROT has even contrived a method of working by the machine in this style without the assistance of tearers.

COPPER-PLATE PRINTING.—To produce more delicate patterns than could be engraved on wood, at the period when printing by the hand-block was the only method employed, copper-plates were introduced in the neighborhood of London about the year 1770, and the cloth was printed from these flat plates with the kind of press used for printing engravings on paper. This method of printing has long been almost entirely superseded by the copper cylinder, which may be regarded as in principle nothing but a simple plate bent into a circular form, and therefore it is quite unnecessary to enlarge upon the flat plate system at any length.

The difference between this system, whether in the form of a plate or a cylinder, and that of the block, whether applied by the hand or by the perrotine, consists in the fact that the design or pattern, instead of standing out from the general surface, is cut, sunk, or impressed upon it in *intaglio*, so as to be lower than the surface. In printing, therefore, with the plate or cylinder, the whole of the engraved surface is first covered with the color, and then means are employed to remove this from the smooth part of the surface, leaving it in the hollow or sunk parts of which the pattern consists; and by applying sufficient pressure the surface of the stuff to be printed is forced into these hollows, from which it extracts the color and receives the impress of the pattern.

CYLINDER PRINTING.—The introduction of the copper cylinder, engraved in the manner of the flat plates, by which it was evidently suggested, formed, as already remarked, by far the most important improvement ever effected in the art of calico-printing. It has also been stated—page 568—that this invention is claimed to have been first made by a calico-printer named OBERKAMPF, at Jouy, in France, but was afterwards independently discovered by a Scotchman of the name of BELL, and was first successfully applied in Lancashire about the year 1785, by the house of LIVESEY, HARGREAVES, and Company. The latter part of this statement is quite correct; but OBERKAMPF's claim to be the first inventor of the cylinder, although it will be found acknowledged in all the works on calico-printing, is really without foundation. Indeed it must appear remarkable and unaccountable, even on a *primâ facie* view of the case, that if so important a discovery was first made in France, at any time prior to the year 1785, its successful application should not have been achieved in that country till many years after it was firmly established in England—not indeed till the beginning of the present century. The simple truth of the matter is, as now clearly established on incontestable evidence, and admitted by M. PERSOZ himself, that OBERKAMPF imported the engraved cylinder from England, and first introduced it at his establishment at Jouy in 1800. M. DOLLFUS GONTARD, an eminent French printer, in a letter addressed by him to M. HUGUENIN CORNETZ of Mulhouse, distinctly states that OBERKAMPF was the first person in France who used the engraved cylinder, and that he was indebted for all the details of the invention, and all the machinery connected with it, to an English mechanic, who remained fifteen or eighteen years attached to his establishment. The name of this English mechanic is given by the writer of the létter in question as M. HANDRÉS, probably a French corruption for ANDREWS, or some similar name. M. GONTARD affirms that OBERKAMPF's first productions in this kind of printing appeared in 1800, and adds that in 1801, and the five following years, the demand for these productions, though limited to one color, and the simple mignionette pattern, was immense. EBINGRE, another calico-printer, who had been formerly a workman in OBERKAMPF's establishment, discovered the secrets of the new process through some of his old associates still employed there, and, in conjunction with a person of great mechanical genius named LEFÈVRE, erected in his own establishment machines on the same principle, which afterwards came into pretty general use.

Such was the history of the introduction of cylinder-printing into France, from which it appears that OBERKAMPF has no claim whatever to the invention; and this is even admitted by the very terms in which his title to it is asserted by the French writers; for all agree in dating it no further back than the beginning of the present century, when cylinder-printing had already been successfully carried on in England for a period of at least fifteen years. For example, in a French work, entitled *Elementary Lessons in Chemistry*, which was published at Rouen in 1839, it is stated that prior to the year 1801, the calico-printers had only two methods of printing, the hand-block and the flat plate; but at this period the celebrated OBERKAMPF, of Jouy, attempted in his fine printing establishment, so long without a rival, to print with engraved copper cylinders. This new method, continues the French writer, which the Manchester printers were not long in adopting and improving, so as to render it at once simple and expeditious, produced a revolution in the art, the effects of which were incalculable. This account of the case is simply amusing, and would indeed have been scarcely worth refuting, had it not been taken up and repeated, so far as regards the ascription of the first invention of the system to OBERKAMPF, even by English writers, who knew and stated at the same time that the method was practised in England with complete success so early as in 1785.

With regard to the actual invention of the system, this must be referred to a date still earlier. POPE, in his *Manual of Discoveries*, states that, in 1770, Messrs. CHARLES TAYLER and THOMAS WALKER, of Manchester, printed fabrics with wooden cylinders, on which the designs were engraved in intaglio. PERSOZ considers it more than probable that these cylinders were formed, not of wood, but of copper plates bent round, and soldered at the edges. On the other hand, it may be doubted whether they were not constructed of wood, but cut in relief like the common block, which seems to be the method that would have most naturally suggested itself in connection with the idea of a cylinder at that period. At the same time, it is quite possible that this may have been, as PERSOZ conceives, the first attempt to apply the invention of BELL, and that, having proved a failure in the first instance, from certain defects of construction, it was only applied with success in 1785.

The Editor has been thus minute and particular in stating these facts, because it has been usual to ascribe to OBERKAMPF the principal merit of this important invention; a merit to which it appears, even on the authority of French writers themselves, that he has not the shadow of a claim, even as a second and independent discoverer. Cylinder-printing is purely a British invention, and the entire and undivided honor of the discovery must be given to BELL.

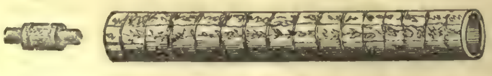
Engraving the Cylinders.—It has been stated that the first cylinders were formed of plates of copper bent round into a cylindrical form, and soldered at the edges. It is evident that to engrave such cylinders all over with the multitude of minute figures which exist in many patterns, must have been a work of great labour, difficulty, and expense. The cylinders, which vary in length from thirty to forty inches, and in diameter from four to twelve inches, are now turned from a solid piece of metal, accurately bored through the axis; and instead of engraving the entire surface by hand, the pattern is *impressed* upon them by a most ingenious transferring process, which greatly diminishes the expense. This process is so well described by **Baines**, that we cannot do better than give it in the words of that writer:—

The principle of this invention, says **Baines**, is the same which Mr. **Jacob Perkins** applied to the multiplication of plates for the printing of bank notes, and Mr. **Perkins** has the reputation of being its inventor; but the process had been practised in Manchester some years before he came from America to settle in London. Mr. **Joseph Lockett**, engraver for calico printers in Manchester, introduced this system about the year 1808; he may be considered as at least one of the inventors, and he certainly did more than any other person to perfect it. The method of transferring is as follows:—The pattern intended to be engraved is so arranged in the first place by a drawing made to agree with the circumference of the copper cylinder, as that it will join and appear continuous when repeated. This is then carefully followed by the engraver, and cut or sunk on a small steel cylinder, about three inches long and one thick, so softened or decarbonized as to admit of being easily cut. The steel is then tempered or hardened, and by means of pressure against another cylinder of softened steel, a fac simile is made *in relief*, that is, raised upon the surface. The second cylinder is then hardened in the same way, and it becomes hard enough to impress the whole engraving, even to the most delicate lines, on the copper cylinder, when pressed against it in a machine. The small cylinder originally engraved is called the *die;* the second cylinder, which is in relief, is called the *mill.* The latter is successively applied to the whole circumference of the copper cylinder, which is thus entirely covered with the pattern, as finely wrought as if it had been directly produced by the tool of the engraver. The surface of the die originally engraved is not more than about one-fiftieth part of the surface of the copper cylinder, and the engraving itself is therefore multiplied *fifty-fold.* By this means the most delicate designs, which would occupy an engraver many months to effect by hand, can be completed in a few days; of course the cylinders are produced at a much less price, and they may be executed in a very superior manner. Should the copper cylinder be so far worn as to require the pattern to be re-engraved, it can be done by the same process with amazing rapidity, and at a very trifling cost, as the mill is already prepared.

The annexed engraving—Fig. 376—exhibits the steel mill, A, on which the pattern is in relief, and from which it is transferred in intaglio to the roller, B. The die, which is a small roller, similar to A, is engraved by hand; all the rest of the operation is performed by transference.

Sometimes the die is cut on a flat surface, and the pattern transferred in relief to the mill by a suitable mechanism. In other cases the die is cylindrical, and the mill flat. The pattern is also sometimes produced by etching, in which case the polished cylinder having been heated, is covered with a thin coat of varnish, such as is used by historical engravers. The pattern is then traced on the cylinder with a diamond or steel point, and aquafortis is afterwards applied to the surface, by which the parts exposed become corroded or engraved. A complicated and ingenious system of tracing-machinery, invented by Mr. **Lockett** of Manchester, is capable, like the kaleidoscope, of producing an endless variety of patterns, which have the advantage at the same time of not being dependent on mere accident for the changes evolved. Eccentrically engraved cylinders, covered with a ground-work for patterns of great variety and beauty, are largely exported from Manchester, and the foreign printer adds the pattern to suit the taste of his customers. The electrotype has also been used for producing the design on the printing cylinder, but not hitherto with much success.

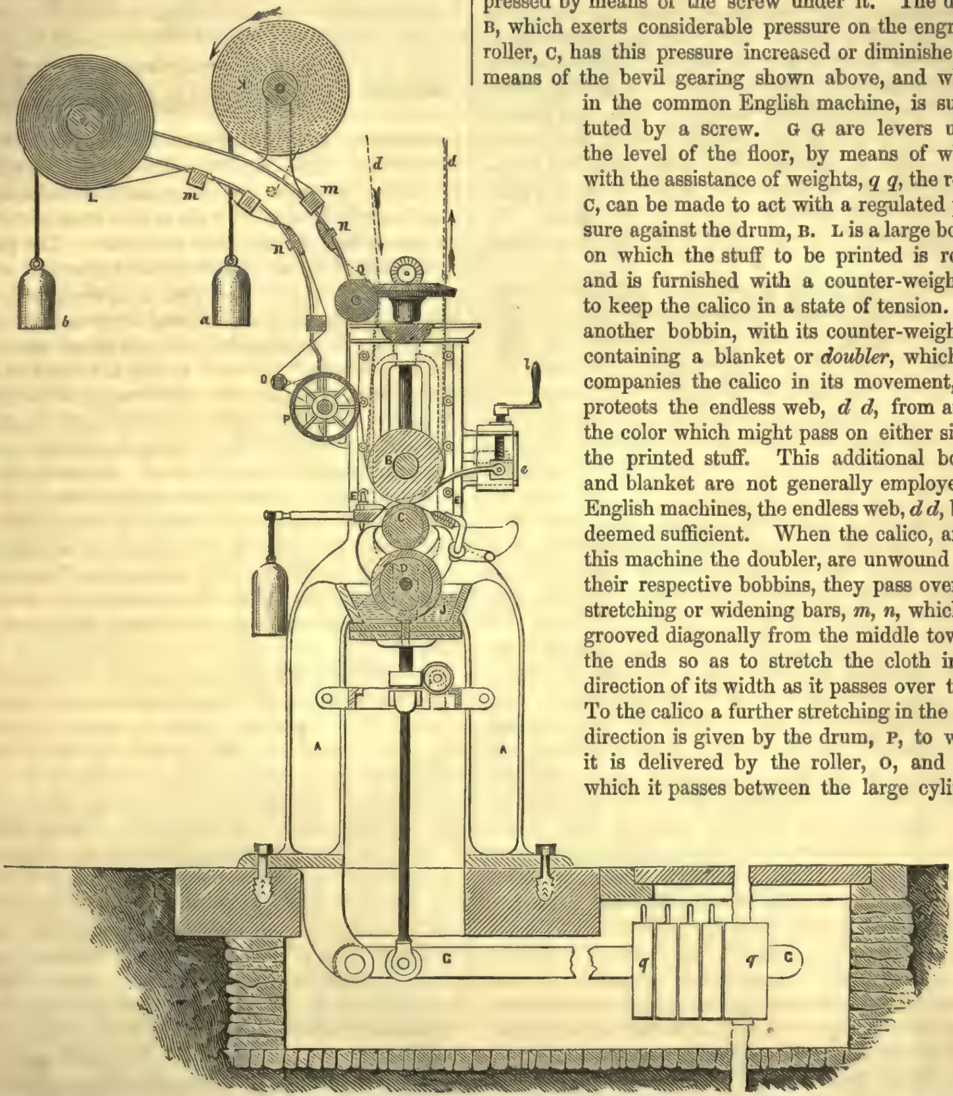
Fig. 376.



The English calico-printers possess a great advantage over their foreign competitors from the cheapness of engraving in this country, and the variety of patterns they can command. The English engraved copper roller is the best produced, and is an article of export to all parts of the world where printing is carried on. The French, with all their neat-handedness and ingenuity, says Dr. **Ure**, can produce nothing approaching in excellence to the engraved cylinders of Manchester—a painful admission, he adds, universally made to him by every eminent manufacturer in Alsace, whom he visited on a tour through that flourishing department. Copper rollers form a very important item of investment in the printer's capital, some of the larger print-houses holding stocks of engraved rollers valued by them in varying sums from £50,000 downwards. The value of one of these cylinders before engraving varies from £5 to £7, and the cost of engraving from £5 to £10. The engraving affords employment to a large number of skilled hands, capable of producing every variety of effect, equal to any efforts from the burins of the best engravers of the day.

Single Cylinder or One-color Machine.—The principles of the operation of calico-printing by the cylinder will be understood by reference to the annexed engraving—Fig. 377—which represents a vertical section of a French one-color machine, constructed on improved principles by M. **Huguenin**. It differs only in a few unimportant details from the common English machines, and is therefore selected as possessing some novelty for the English printer, while at the same time, for the general reader, it perfectly illustrates the principles of cylinder-printing. A is the iron frame-work; C, the cylinder or roller bearing the engraved pattern, and revolving in contact with the drum, B, on the one hand, and on the other with the color-roller, D. The latter is covered with stout woollen cloth, and works partially immersed in the color-trough, J, as shown in the figure. This trough rests on a plate which is raised or depressed by means of the screw under it. The drum, B, which exerts considerable pressure on the engraved roller, C, has this pressure increased or diminished by means of the bevil gearing shown above, and which, in the common English machine, is substituted by a screw. G G are levers under the level of the floor, by means of which, with the assistance of weights, *q q*, the roller, C, can be made to act with a regulated pressure against the drum, B. L is a large bobbin on which the stuff to be printed is rolled, and is furnished with a counter-weight, *b*, to keep the calico in a state of tension. K is another bobbin, with its counter-weight, *a*, containing a blanket or *doubler*, which accompanies the calico in its movement, and protects the endless web, *d d*, from any of the color which might pass on either side of the printed stuff. This additional bobbin and blanket are not generally employed in English machines, the endless web, *d d*, being deemed sufficient. When the calico, and in this machine the doubler, are unwound from their respective bobbins, they pass over the stretching or widening bars, *m*, *n*, which are grooved diagonally from the middle towards the ends so as to stretch the cloth in the direction of its width as it passes over them. To the calico a further stretching in the same direction is given by the drum, P, to which it is delivered by the roller, O, and from which it passes between the large cylinder, B, and the engraved roller, C. At first the latter was made to dip directly into the color-trough; but by the intervention of another roller, D, the color is more equally spread, and is forced into the lines or cavities of the engraving. By either method, however, it is communicated to the whole surface of the engraved rollers, whereas it is only required in the depressed parts that form the pattern. To remove it from the smooth surface, an elastic steel blade, E, reduced to so fine an edge as to take off the superfluous color without scratching the copper, is placed in contact with the cylinder, and another similar blade, which does not appear in this machine, is generally placed on the other side of the cylinder to remove any fibres it may have contracted from contact with the calico.

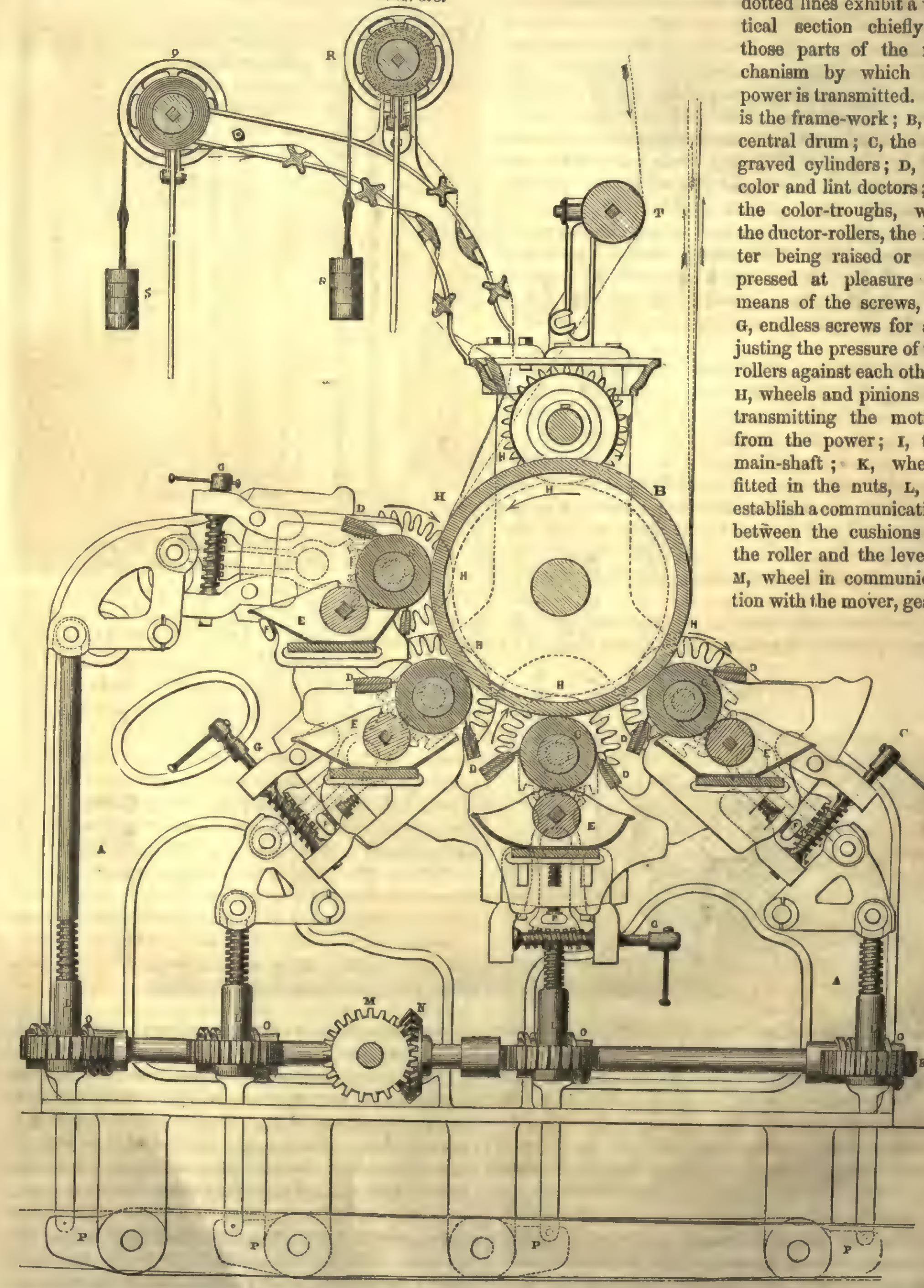
Fig. 377.



These blades have received the name of *doctors*, which, as BAINES remarks, may be a workman's abbreviation of the word *abductors*, applied to them from the purposes which they answer; or may have been given from a vulgar use of the word *to doctor*, meaning to set to rights. The one first mentioned is termed the color-doctor, and the other the lint-doctor. By a screw turned by the handle, *l*, acting upon the lever, *e*, any required inclination is given to the color-doctor; but these arrangements may vary according to circumstances. The doubler, passing round the stretching roller, Q, arrives with the calico under the drum, B, separating the former from the endless web, *d d*, the course of which, in connection with that of the other parts of the apparatus, is shown by the arrows.

French Four-color Machine.—The annexed view—Fig. 378—of another French machine, partly in section and partly in elevation, and calculated for printing four colors, may likewise be interesting to the English printer. The dotted lines exhibit a vertical section chiefly of those parts of the mechanism by which the power is transmitted. **A A** is the frame-work; **B**, the central drum; **C**, the engraved cylinders; **D**, the color and lint doctors; **E**, the color-troughs, with the ductor-rollers, the latter being raised or depressed at pleasure by means of the screws, **F**; **G**, endless screws for adjusting the pressure of the rollers against each other; **H**, wheels and pinions for transmitting the motion from the power; **I**, the main-shaft; **K**, wheels fitted in the nuts, **L**, to establish a communication between the cushions of the roller and the levers; **M**, wheel in communication with the mover, gearing with another wheel, **N**, on the shaft, by which it transmits its motion to the endless screws, **O**, gearing with the wheels, **K**; **P**, levers placed under ground, and charged with weights according to the pressure required; **Q**, a roller containing the stuff to be printed; **R**, a roller containing the doubler which circulates along

Fig. 378.

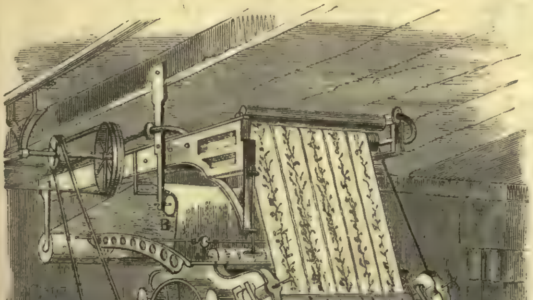


with the calico to protect the endless web from being stained with color at the margins; S, weights for keeping the calico and the blanket in a state of tension; T, a roller to guide the endless web in its course.

The action of this mechanism will be obvious from the explanation already given of the one-color machine. Each of the engraved cylinders, C C C C, contains only part of the pattern; and, supposing the colors in the pattern to be red, blue, yellow, and lilac, one contains the red, another the blue, the third the yellow, and the fourth the lilac parts. It evidently requires much care and attention so to prepare and adjust the cylinders that, as the calico proceeds round the drum, and receives the impression from each cylinder in succession, the different parts of the pattern shall fall into their proper places. When this adjustment, however, is once made, the action proceeds without interruption, and with the most perfect regularity till the whole is printed.

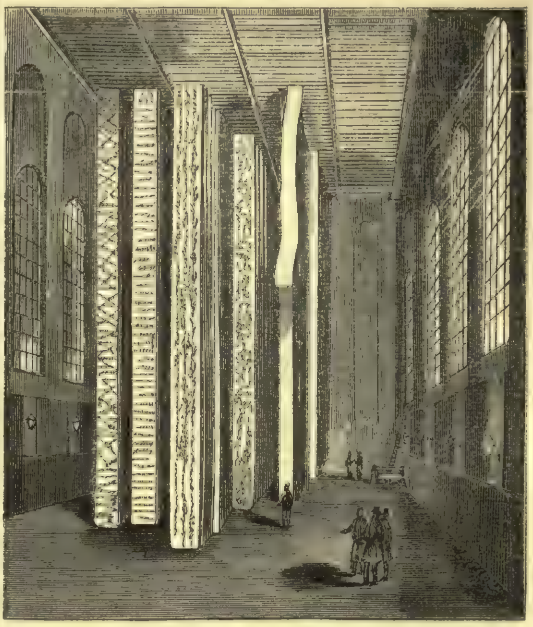
Latest Machines.—The preceding sectional figures sufficiently explain the principles of cylinder printing. Of late years, however, very great improvements have been effected in this mechanical department, and machines are now constructed which are capable of printing a great many colors. Fig. 379 represents an elevation of an eleven color machine, as working at the extensive and well-regulated establishment of Messrs. **Hoyle** and **Sons**, at Manchester; and Fig. 380 is a representation of a drying-room, sketched somewhat hastily in the same establishment. Fig. 381, on the next page, is a delineation of a magnificent machine erected by Messrs. **Mather** and **Platt** of Salford, for Mr. **Joseph Leese** of the Ardwick Print Works, Manchester, ordinarily working with eighteen, but capable of printing twenty colors.

Fig. 379



When the difficulty of adjusting even a two or three color machine is considered, it will be evident to the reader that no small ingenuity must be displayed in fitting together the various parts of a machine for printing ten, twelve, or even twenty colors. In printing by hand, it is the operator who, by his carefulness and dexterity, gives to the patterns the correct character which constitutes beauty of workmanship; in cylinder-printing, it is on the regular movement of the machine, and on the quality of the colors, that success essentially depends. Now, in machines for printing several colors, the number, not only of the engraved rollers, but of all the other elements of the machine, is increased in the same proportion; since each cylinder must be provided with its color-trough, its ductor-roller, its color and lint doctors, and the other accessories connected with them. A large machine of this description becomes, therefore, a very complex piece of mechanism, requiring the most scrupulous attention, and very careful and accurate adjustment on the part of the superintendant. He has not only to regulate the working of each of the parts which co-operate towards the printing of one of the colors, but he must so adjust the movement of all the various parts of the whole mechanism, that each of the different colors may exactly fit into its place. This adjustment is often attended with much difficulty, on acount of the stretching of the stuff in passing successively under the different rollers. The endless web, also, is liable to deviate from its proper course, passing sometimes to the right, sometimes to the left, and drawing along with it the calico to be printed. Lastly, the engraved cylinders not having all the same diameter, cannot be moved with the same speed, and arrangements must therefore be made to regulate the movement of each. These are some of the difficulties which, among many others, so long retarded the application of many-color machines, and even

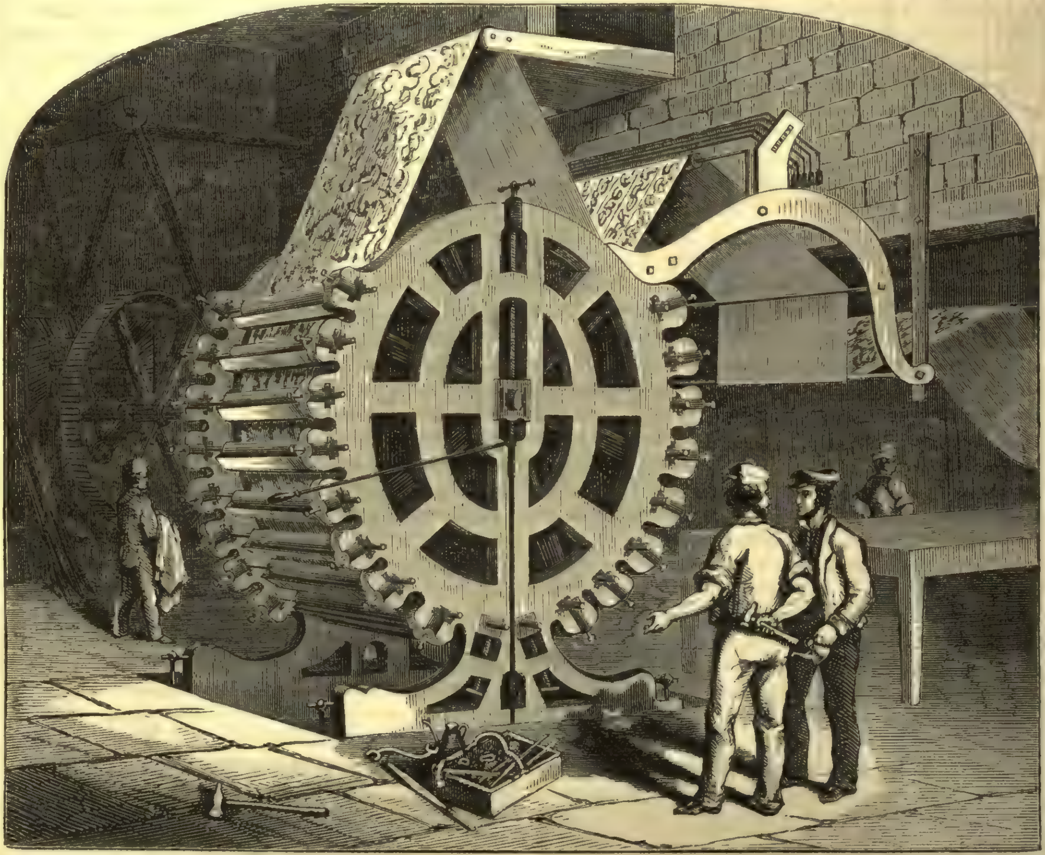
Fig. 380.



at first induced several printers to abandon the idea altogether.

To enable the attendant to adjust the engraved rollers in their proper positions, these rollers are furnished with marks placed at a part of the pattern where they can have no injurious effect upon the printing. In proceeding to adjust them, the overseer, applying his pencil, covers with a dark color the mark or *picot* of the first cylinder, to which he gives one turn; he then applies the pencil to the picot of the second, to which he also gives a turn, after having put it in connection with the first; and so on for the rest, till he has found the proper adjustment on the doubler or endless web. In this manner all the rollers are regulated according to the first; the printing of a piece is then commenced, but operating with so low a speed, as to allow of completing in all directions the adjustments which might not have been made exactly at first. For this preliminary trial, it is customary to make use of a doctor which performs the office of a color-trough. This, which is in front of the machine, is placed at the lower part of the cylinder, but making such an angle with it, that the space comprised between its plate and the surface of the cylinder may act as a reservoir for the color. Recourse is had to the same arrangement for printing expensive colors or those of which there is not sufficient quantity to fill a trough. Lastly, that the adjustment may be preserved during the course of a printing, it is requisite that the cloths be always well stretched.

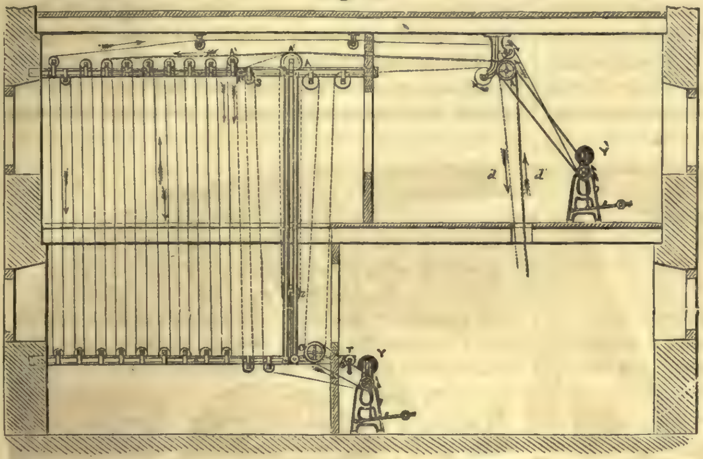
Fig. 381.



It is more particularly in printing several colors, that it is essential for the calico and the doubler to have a regular movement, and that they do not become more stretched at some points than at others, between the cylinders. This kind of printing requires, moreover, that special regard be had to the order in which the colors should succeed each other on the stuff; for if, from want of precaution, a black color were printed before a red color, the color first laid on the stuff, arriving under the second pair of cylinders before being perfectly dry, would always be more or less transferred to the surface of these cylinders, from which it would pass into the red trough, and this last would soon print only brown-red, or puce. To be convinced of this it is sufficient to examine the samples printed twenty years ago by the two-color machine.

Besides these inevitable accidents occasioned by mixtures of colors, there are others which arise from the pressure. A color too thin and too slow to dry, if printed by the first roller, would not remain at the surface of the stuff, but after being pressed between the second or the third cylinder, would penetrate through the stuff, and would then present only a poor and scratchy impression. The only means of abating these effects of mixture or of compression, is by composing patterns as much as possible in columns or stripes, choosing a thickening which shall have little permeability, and lastly, taking means to have the cloth as warm as possible. This last consideration merits serious attention. In printing with a single cylinder, very delicate patterns may be printed in thin colors, without fear of seeing the color run, for it is at once arrested and quickly dried on entering the drying chamber; in printing with several colors, if one wishes to prevent the transference of the color from one cylinder on to another, or the effects of the pressure on a color newly applied, which it tends to force into the pores of the stuff instead of allowing it to remain at the surface; lastly, if it be desired to obtain delicate impressions with the last as well as the first cylinders, it is indispensable to heat the cloth, otherwise the color, which must be applied thin, not being promptly arrested, would be pressed in or taken off between the other cylinders, and the pattern would lose all its clearness.

Fig. 382.

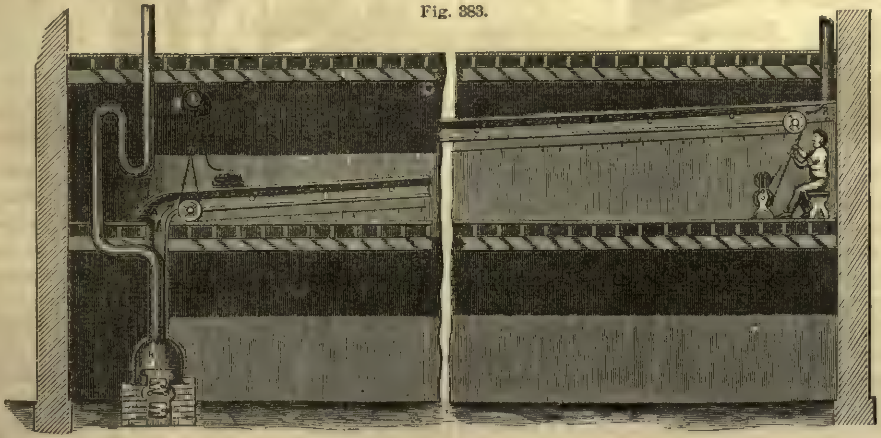


The many-color machine is, without contradiction, the most delicate of all the printing machines, and that which requires the greatest intelligence in its use; but, the printer who has studied it to the bottom, who knows its working, who knows how to bend it to all his requirements, to turn to account all its resources, possesses an immense advantage; for, not only does he derive benefit from the regular effects of the juxtaposition of several colors from those of their superposition, which has, for its result, the combination of one color with another, and the formation of a complex color, or the discharge or reserve of one or more colors, or lastly, the production of new colors by conversion, but further, he can give rise to an infinity of compound forms, by indefinitely combining the simple forms which are at his disposal.

DRYING ARRANGEMENTS.—The annexed engraving—Fig. 382—shows an arrangement for hard-drying the color or mordant, upon the stuff, as soon as it passes through the printing machine. This drying apparatus, in one form or another, is so essential that it is considered a part of the printing machinery. The course of the cloth, after passing between the drum and the engraved cylinder, is shown in the cut commencing at *d*, where it was broken off in Fig. 377, continuing for some time accompanied by the doubler and the endless web, and passing, by circuits, over a double row of rollers, till it is finally wound upon the bobbin, Y′, while the doubler is received upon another bobbin, Y, after having traversed only four of the rollers; and the endless web, constantly kept in a state of tension by a moveable pulley, Z, acted upon by the handle, T, returns under the drum, B—Fig. 378—after having circulated over some of the rollers. The doubler, as already stated, is dispensed with in English printing machines.

The Hot-Flue.—Under the name of the *hot-flue*, various methods of drying printed or padded goods at a somewhat elevated temperature, have been adopted; and one of the latest and most improved arrangements for this purpose will be given in connection with what is termed the *padding style;* but one of the oldest and simplest, and that probably from which the term itself, *hot-flue*, is derived, is shown in Fig. 383, where H is a round iron stove, from whose top a wide square flue, A R, represented, for want of space, as broken in the middle, proceeds upward in a direction slightly inclined to the

Fig. 383.



horizontal. This flue is from twenty-five to thirty yards in length, a little broader than the common width of the stuff, and from twelve to sixteen inches in depth. At its lower part, A, it receives the current of air heated by the body and capital of the stove, H, and at its upper part, B, it communicates with the chimney, D. In this flue there are pulleys, with endless cords or bands, which suspend by hooks, and conduct the web of calico from the candroy or reel, O, where the operative sits to near the point, A, and back again. At A the drawing pulley connected with the main shaft is shown. One end of the moist calico upon the reel, O, is hooked by the operative to the endless band which draws it into the flue at B, and passing down the channel it encounters a current of air, hotter and drier as it proceeds, till arriving at A, or having been circulated a sufficient number of times, it is detached from the endless band, and taken up by a drum at E, from which it is deposited in a perfectly dry state.

PREPARATION OF THE COLORS AND MORDANTS FOR PRINTING.—To diffuse uniformly a color, or one of its components, such as a mordant, over the surface of a stuff, it is sufficient to convert either the one or the other into a liquid state, by means of a dissolving agent, so selected that it may not dispute with the fabric the power which the latter possesses of uniting with the tinctorial matter or mordant, and to impregnate the stuff with this solution under certain precautions; these are the operations daily practised in dye-works. But when, on the contrary, a color is to be applied on certain determinate points of the stuff, as in printing, to form a pattern upon it, more or less regular, it is a matter of absolute necessity that it be previously *thickened;* otherwise it would run or flow, and the patterns would lose their regularity, assuming both different shapes and different shades. Now, if to those who are little conversant with printing, it may seem to be an easy matter to accomplish this, namely, to give to the colors the degree of viscidity which they require to prevent their flowing—printers themselves express an opposite opinion. M. DANIEL KŒCHLIN, for example, says in his Memoir on Mordants, that the art of thickening mordants, or of giving them the consistence necessary to render them fit for different sorts of printing, demands long practice, and that, without doubt, in many cases, the success of the printing and of the combination of bases with the stuff depends upon it.

It would be in fact a perfectly erroneous idea of this operation, to think that every organic substance which possesses the property of giving viscidity to water, may on that account alone serve for the thickening of a color intended to be printed on cotton, silk, or wool. Sugar, for example, renders water viscous, and yet this body is excluded from use in the thickening of most colors, since the chemical action it exerts is such that a mordant mixed with it loses much of its affinity for the stuff. Many vegetal mucilages are known, and yet none can replace the mucilage *par excellence* which is yielded by gum tragacanth, because all of them produce the effect of masking a part of the chemical properties of the mordants, as tartaric acid, for example, and other fixed organic substances would do.

The first quality required in a thickener is, that it do not dispute with the goods the power of uniting with the coloring matters, otherwise, on removing the thickening, the color would disappear also. Thus, it would not be difficult, by modifying tartaric acid by heat, and rendering it uncrystallizable, to make it serve for thickening an aluminous mordant; but, in presence of that acid, the stuff would refuse to take on the smallest quantity of alumina.

Thickenings.—The substances which have been recognized as the fittest for the thickening of colors are the following:—1, Wheat starch; 2, Flour; 3, Gum-arabic; 4, British gum, or torrefied wheat starch; 5, Torrefied potato starch; 6, Gum-senegal; 7, Gum-tragacanth; 8, Salep; 9, Pipe-clay, mixed with gum-arabic or senegal; 10, China clay, mixed with gum-arabic or senegal; 11, Dextrin; 12, Potato starch; 13, Rice starch; 14, Sago, common and torrefied; 15, Sulphate of lead, mixed with gum-arabic or gum-senegal; 16, Sugar; 17, Molasses; 18, Glue.

In the choice which he makes of a thickener, the printer must be guided by several considerations; and the following excellent rules have been laid down by PERSOZ on this subject:—

1. He must take into account the temperature which the thickening of a color requires; for if the latter is of a nature to be decomposed by heat, starch and flours must be rejected, since these substances only incorporate well with the tinctorial matters, and thicken them properly, when mixed with them in a heated state.

2. The state of saturation of the color; for if it be strongly acid, starch and flours would be still less applicable to the purpose, as being too sensitive to the action of acids, all of which tend to liquefy or thin the colors which have been thickened with these substances, and to set up changes in them which vary every hour of the day. If, on the contrary, the color be alkaline, it will be necessary to ascertain whether it holds in solution earthy or metallic oxides. In the first case, all thickenings coagulable by alkalies must be excluded—such as the starches and flours; but gum, torrefied starch, and lastly, dextrin, may be employed; in the second case, all the thickeners which have just been mentioned, being of a nature to give rise to insoluble combinations with the metallic oxide, would be excluded, and recourse would be had either to sugar or to saccharate of lime.

3. Regard must be had to the combinations or decompositions which take place between the constituent principles of a color or a mordant, and this or that thickening, according to the nature of the mordant and the color, or according to their state of concentration. Thus, since the tri-acetate of lead precipitates, by its base, all the fixed organic substances with the exception of sugar, this last substance can alone be employed to thicken it. The salts of iron which coagulate the gums arabic and tragacanth, are properly thickened only by wheat and potato starch, torrefied starch, léiocom, and dextrin, which exercise no effect upon these salts; chloride of tin and gallate of iron, which are coagulable only by gum senegal, may be inspissated by all the other thickening substances; the acetates of iron and alumina, which neither coagulate nor precipi-

tate with any of the substances above-mentioned, may be thickened by any of them which one prefers to employ. With regard to astringent matters, or such as are rich in tannin, as these have sometimes a tendency to cause colors to coagulate, it is necessary either to employ suitable agents to prevent this—acetic acid for example—or to change the thickening.

4. The degree of consistency which is to be given to a color to make sure of its taking on, must likewise be considered; for the rapidity with which it dries may exercise a great influence on its intensity, when it has been formed and fixed on the stuff. Thus, iron and aluminous mordants strongly thickened with gum, and consequently of a nature to dry with great rapidity, produce on the stuff shades incomparably less full than the same mordants employed in the same degree, but thickened with starch and of greater consistence.

5. The intensity of the shade which it is desired to obtain must be taken into consideration; for *cæteris paribus*, a mordant of the same strength, thickened with gum tragacanth and with potato starch, gives shades infinitely more intense than that which has been thickened with gum arabic and with torrefied starch, for this reason, that under the same volume of liquid or of mordant there is much less of fixed organic matter when the gum tragacanth and starch are employed, than when use is made of gum arabic or of torrefied starch. Let it be desired, for example, to thicken one gallon of acetate of alumina to 5·5 Twaddell, in this case nine to eleven ounces of gum tragacanth would suffice to bring the color to the desired consistence, whilst it would require about twenty-four ounces of starch—in reality twenty ounces of solid matter, the starch usually containing eighteen to twenty per cent. of water—and to attain the same consistence one must employ at least fifty-seven ounces of gum arabic.

If the intensity of the colors furnished by a mordant is in inverse proportion to the quantity of solid matter which it requires to be properly inspissated, the cause of this may be found partly in the property possessed by fixed matters of masking a certain quantity of the mordant, by forming with it a combination on which the stuff is without action, and partly in this fact, that a color which, under the same volume contains less of solid matter, always undergoes by desiccation a kind of concentration or shrinking much more considerable than when the thickening is strong.

6. Regard must be had to the hue of the thickening; for, although when it happens that a color applied and fixed on the stuff resists all the mechanical operations of the scouring by which it is cleared of the thickening that has been employed, one is in that case relieved from the necessity of attending to the more or less colored state of this thickening, yet, when the color, on the contrary, does not resist a thorough scouring, and a certain quantity of the thickening remains adherent to it, the case is different. It is absolutely necessary, indeed, to abstain from inspissating delicate colors by means of colored thickenings which would injure them by adding their own shade. If torrefied starch, for example, be used to thicken rose or blue, to be then printed on a woollen stuff, on which neither of these colors will very well resist washings, the consequence is that by combining with the yellow-brown tint of the thickening, the first will become brownish and the second greenish; but, on the contrary, the same thickener is advantageously employed for thickening the same colors on calico, on which they become definitively fixed, only after the stuff has been perfectly scoured.

7. The facility with which a thickening may be discharged from the stuff must also be taken into account; and it will at once be seen that this consideration is intimately connected with the preceding, namely, that a colored thickening ought to be employed more rarely in proportion as there is greater difficulty in removing it by the washings; at the same time, attention must be given to the fact, that a thickening, even when colorless, sometimes produces the effect, according as it remains adherent or not, of causing the stuff to contract properties which diminish its value. M. D. KŒCHLIN-SCHOUC has, in fact, shown that gum Senegal employed as a thickener, combines in so intimate a manner with the stuff and with the mordant when it has undergone an acid fermentation, that it can no longer be discharged from the goods by the ordinary means, and gives them a stiffness or rigidity which always compromises the operations of the printing and dyeing.

8. Regard must be had to the shrinking or contraction which the thickenings cause the stuff to undergo, when several colors are to be successively printed. If, indeed, a gummy substance spread on a piece of wood or sheet of glass always cracks on drying, in consequence of such surfaces presenting too much resistance to follow the film of gum in its shrinking movement, a quite different result is the consequence when this solution is printed, in any quantity, on goods which yield by their softness to the contraction of the gum, and thereby acquire wrinkles or creases always more or less prejudicial in the printing of different colors. These accidents are usually prevented by the use of a mixture of thickenings which do not produce this shrinking movement, at least not in the same degree, or by employing pipe-clay, which acts in this case a purely mechanical part, by rendering the gum less persistent.

9. Attention must be given also to the order in which the colors are superposed in the printing; for very often, when one is obliged to print several mordants alongside one another, the engraving must be so combined as to prevent, by a superposition of the light on the dark color, those breaks of the continuity to which the slightest inattention on the part of the workman would give rise, if the mordants were only put in juxtaposition to each other. It is obviously essential, in this case, that the thickenings be not of such a nature as to react on each other and thus to confound the colors. The first color that is printed of a pattern is usually the darkest and the thickest; it is thickened with starch, and the second with gum. In the case of delicate cylinder printing, the first color is thickened with roasted starch, British gum, or dextrin, and the printing of the ground with gum Senegal.

10. The nature of the engraving must be taken into account; for when the lines are very fine and the work elaborate, it is evident that coarse substances cannot be used as thickeners. On this subject it may be suffi-

cient to remark, that the printing of a delicate pattern is always performed with infinitely better chances of success by means of gum arabic or torrefied starch, than with starch in the crude state, or flour; on the contrary, if the pattern has massive parts which should stand out in relief, the starch and flour will perfectly meet the views of the printer. In short, it may be stated as a general rule, that when the engraving is of little depth the printing should be done with colors or mordants but little thickened; when, on the contrary, it is deeper, one should employ thick colors; nevertheless, there are limits on both sides which must not be exceeded. When the pattern is composed of very deep parts along with others which are of little depth, it is necessary to employ a certain proportion of starch, or to add to the color, if gum be used, a substance which will give it sufficient body to ensure clearness and equality of impression in the deep lines, leaving it at the same time thin enough for that of the light lines.

11. The manner in which the thickening behaves in presence of a color or mordant is another point of importance, for it is essential to good results that the latter should remain during the whole time of its being printed at that degree of consistency which has been given to it by the thickening; otherwise, if it should become thicker or thinner, the influences of these variations would manifest themselves in the printing in a very annoying manner; such variations are prevented by the intervention of a suitable substance added in very small quantity. It will be sufficient, for example, to add a little gum or starch to prevent coagulation.

12. Lastly, besides the necessity of attending to the qualities of the gums and starches employed, an important element for consideration in making a selection among them, is sometimes the cost. When gum can only be procured at a high price, several printers endeavor to replace it by other thickenings in almost all the colors with which it is used.

To these considerations it may be added that pipeclay is employed not only to prevent the too powerful shrinking of a color, which has the effect of contracting the goods, but further, to prevent the running or flowing of a too thin color, and thus to confine it to the spot on which it is deposited by the printer, as well as to aid in the scouring of the color, which it always renders more easily acted on by water. Gelatine is also employed as a thickening, having the effect of giving more body to the color, without sensibly increasing the weight of the solid matter which thickens it, while at the same time contributing, by the modifications which it undergoes in presence of an acid, to render the color hygrometric. With the same view, and also with that of opposing the coagulation of a color, the chloride or the nitrate of zinc are likewise employed; and lastly, saccharate of lime.

Having thus stated the nature of the different thickenings, and those considerations which ought to determine the choice of them by the printer, the Editor now proceeds to explain the processes to be followed for the thickening of a color, and to lay down in a general manner the quantities of thickenings which it is proper to employ according to circumstances.

When gum arabic is used, it is either dissolved in water, so as to form a concentrated solution which is left to settle, then filtered if necessary, and added in suitable proportions to the mordant or color to be thickened; or the gum is added in a crushed or pulverized state to the color itself, to dissolve in it either cold or hot, according to the nature of that particular color. In the first case, pieces of gum, as they are taken from the casks, are placed in a basin, and after being simply wetted, they are shaken together so as to detach by their mutual friction an opaline substance which tends to set up the fermentation of the gum, and its passage to the sour state.

The colors with which starch is used are thickened also in two ways: either the starch is made into a very dense jelly, and the color to be thickened then incorporated with it—a process however, which is rarely employed—or the starch is mixed with the liquid and all or part of the ingredients which should enter into the color; the mixture is then heated, stirring it till the starch becomes gelatinised; and lastly, the color is boiled, for ten, twenty, thirty, to forty minutes, according to its nature, as well to give it homogeneity as to render it more fluid; for many colors are much thicker at the moment when the starch has just jellied than after boiling, which may be attributed to two causes: first, to the effect produced by the heat on the jelly, which liquefies in the long run; and secondly, to that attraction which the acids contained in a color may still exercise upon it. Further, it is always prudent, when acids are to enter into a color, not to incorporate them with it till after the thickening has taken place. The mixture when sufficiently boiled is withdrawn from the fire, and, either immediately or after it has cooled a little, the complementary ingredients are added; lastly, according to its constitution, it is either left to itself, or carefully stirred during the whole time it is cooling. This precaution is particularly indispensable in thickening aluminous mordants, which become turbid by heat, otherwise, the sulphate of aluminia precipitated would only be imperfectly redissolved, and the color would be a complete failure.

The operation just described is performed, either on the open fire in copper pans or boilers, or by the aid of steam in double-bottomed vessels of that metal. Formerly in every color-kitchen, so called, there was placed a series of pans and furnaces to correspond, of a capacity increasing by gradations from half a gallon up to thirty and fifty gallons. In these vessels one or two workmen, armed with strong wooden spatulas, agitated and stirred the color during the whole time which preceded the formation of the jelly, to prevent it from clotting, and also from sticking to the bottom and burning during the boiling. To diminish the trouble and inconveniences attending this operation, thickening by steam has been generally substituted for that by the open fire, as the use of steam secures the printer against the risk of his colors or his prints turning out failures from being exposed to the action of a too powerful fire, or from the negligence of the workman, who may not have agitated his color with sufficient care.

In the French printworks, they have retained the old arrangement of the vessels for boiling the colors, but these, consisting of a series of double boilers of different capacities, are made to communicate with each other and with a steam generator, which transmits to them the caloric necessary for the formation and boiling of the starch-jelly. The vessels are further furnished at their lower part with a tube which allows the water of condensation to run out. For this arrangement of double-bottomed fixed boilers, which are always more or less difficult to empty and clean out, the English printers have substituted a system, by which the coppers are movable, and accessible on all sides to the workmen. This arrangement is shown in Fig. 384. A is a wooden platform, serving for a support to the whole apparatus. B, B, iron pillars with cushions, on which the bearings of the coppers turn. C, C, openings on the pillars, B, furnished with lunettes, to which are fitted tubes for receiving the steam, Fig. 385, which is distributed under the coppers by means of double and single stopcocks. E, double coppers, the structure of which is represented in Fig. 386. These coppers turn on hollow bearings, which, being jointed into one another by tubes, themselves turning in stuffing-boxes, establish a communication between them, and allow the steam to circulate from one double-case into another. F, stopcocks, by which issue is given, from time to time, to the water which proceeds from the condensation of the steam, and which falls into a tub placed immediately under, or runs into a general reservoir; G G, iron handles fixed to the boilers, and which afford to the workmen the means of inclining them at pleasure to pour the color into the tub placed almost immediately under. It is obvious that by means of the openings, C C, placed in each pillar, and the stopcocks, which allow of intercepting at pleasure all communication between two or more coppers, the option is given to heat only the number of coppers that may be required.

Fig. 384.

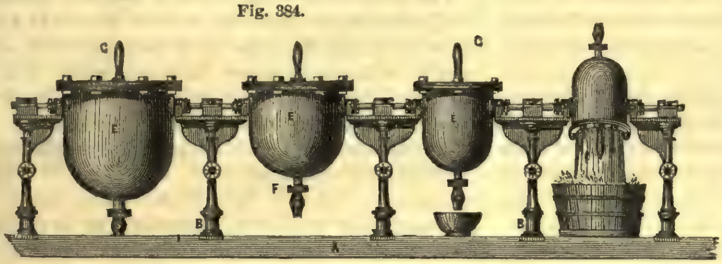


Fig. 385.

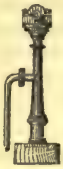
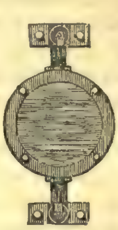


Fig. 386.



Some printers, who had adopted this system, have replaced it by fixed coppers seated in masonry, to prevent both the too rapid condensation of steam which takes place when the vessels are free and exposed to contact with the air, and the escapes which the tension of the steam often causes from the stuffing-boxes. It appears, however, that one might arrive at the same result, and retain the advantage of having the boilers movable, by giving more care to the construction of the stuffing-boxes, and surrounding the lower part of the apparatus with bad conductors. For the rest, there is always an advantage in collecting the distilled water which the condensation of the steam yields, and which may be turned to account for various purposes.

Whether the colors have been thickened on the open fire or by steam, and whatever precautions may be taken, clots, or lumps, are always formed, which it is important to get rid of. For this purpose they are poured in small quantities on a sieve, with meshes of more or less width, through which they are forced by a workman, who rubs them against the sieve as they pass, by means of a brush.

Sometimes they are poured into a large square piece of cloth used expressly for this purpose, and two workmen, by wringing this cloth in the direction of its length, force the colors through its meshes; in other cases, they are *panned*—that is to say, they are introduced into pans or cylinders, in which motion is communicated to balls or bullets, by which they are crushed and comminuted.

When the colors are thickened with roasted starch, with léiocom, or potato-starch, the operation is usually performed in the cold, and in the following manner:—The thickening is poured into an earthen pan with the quantity of liquid necessary to make it into a soft paste; it is worked well to get rid of all the hard parts, and then the rest of the liquid is gradually incorporated with it. If the starch was not completely and uniformly torrefied, the color must be heated and gently boiled, being always guided on this point by the preliminary trial which ought to be made of these substances before using them. This kind of thickening, more than any other, requires that the colors be perfectly *sifted* or *panned;* for the fragments of charry matter or hardened gluten which are met with in it, may very often give rise to accidents more or less serious, especially in cylinder printing, as well from the effects which these substances produce on the engraving, as by the obstacles which they present to the highly important function of the doctors or scrapers.

Gum tragacanth is employed, either as a mucilage or in powder; in the former case, it is sufficient to steep it in a certain quantity of water, in which it swells up, to prepare it for being added to the colored liquor to be thickened; in the second case, it is incorporated with the liquid, taking the precaution to sprinkle it with a little alcohol. It is rarely that this gum is employed alone; for all printers have observed that, while it communicates more vivacity and brilliancy than other thickenings, it imparts to the colors neither the necessary body nor the requisite binding quality, and this consideration, added to reasons of economy, has led to the practice of associating with it a certain quantity of gum arabic or white starch, or a mixture of these two substances.

The quantities of thickenings to employ vary with the nature of the colors, the mode of printing, the depth or lightness of the engraving, and, lastly, with the season of the year at which the printing is performed; for the same color requires different proportions of thickenings in summer and in winter.

To thicken colors or mordants, the average quantities required are as follow:—

If white starch is used, twenty-five to thirty ounces of this substance to the gallon of color. The proportions vary between these two extreme quantities; the highest is suitable for colors to be printed with the block; the lowest for cylinder printing.

If roasted starch or léiocom be used, 5·5 to 7·5 lbs. in winter, and in summer nine to eleven lbs., to give to the color when printed with the block the density which it requires, and about one-fourth less if the same color is printed with the cylinder.

If gum senegal is employed, forty-five to fifty-five ounces per gallon to thicken the mordants of alumina; one hundred to one hundred and ten ounces for violet mordants; but these proportions vary also with the season, and especially with the nature of the pattern and the depth of the engraving. Thus,

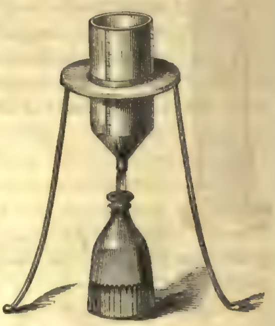
	For a printing in picotage or mignonette pattern.	For a printing with deep lines.
Violet requires per gal.,....	5·00 lbs. of gum.	6·20 lbs. to 6·80 of gum.
Red,.........	3·45, 3·75, 4·00	4·50
Rust-color,....	4·00	5·00
Crockery-ware blue,.......	4·00	5·60

If gum tragacanth is employed, four to five and a-half ounces per gallon of liquid, with double that weight either of gum arabic, or of starch, or, which answers still better, equal parts of starch and gum arabic, that the color may be perfectly fixed. Some printers use a gum water formed of 1 gallon of water and 10 ounces of gum tragacanth with 10 ounces of gum arabic.

It is proper to remark that colors thickened with flour must be boiled for at least an hour to an hour and a half, to give them the homogeneity which is desirable, and that these colors always work better after being some time prepared than when they are recent. Those which are thickened with starch do not require so much boiling; nevertheless it is always useful to boil them so long as to prevent their turning. Starch strongly roasted is, *cæteris paribus*, always employed with much greater success than that which is less so, as it renders the colors less liable to coagulate. Torrefied starches, *et cetera*, employed in the printing of aluminic and ferrous acetates do not give so good results, but they answer perfectly for printing blue, fast green, and aluminate rose.

Viscosimeter.—In proportion as the cylinder has been more generally introduced, the printer has felt the necessity of estimating the degree of viscosity of the color thickened with gum and torrefied starch, which are generally used for this kind of printing, so as to be able at need to give it the most suitable consistence; for we know that this viscosity must necessarily vary with the depth of the engraving, with the nature of the pattern, with the season, with the hygrometrical state of the atmosphere, and, lastly, with the quality of the goods. It was to meet this requirement that M. CHARLES DOLLFUS constructed the *viscosimeter*, based on the consideration, *that the thicker a color is, the less liable is it to run, and vice versa.* This apparatus is very simple; it consists in a cylinder—Fig. 387—of four inches in diameter by twelve in length, terminating at one end in an open cone of five to six inches in length, which gives it somewhat of a funnel shape. To the mouth of this cone is fixed with sealing-wax a glass tube presenting an opening of about one-tenth of an inch in diameter. This species of funnel, which is graduated for introducing into it given volumes of liquid, rests on a tripod standing pretty high, to admit of being placed over a decanter. After filling the apparatus with water up to the mark corresponding to one quart, the liquid is allowed to flow out by the lower opening, determining with watch in hand, the time it takes to flow, to regulate this opening in such a manner that one quart of water may require just two minutes to flow out, a condition which M. DOLLFUS found to be most suitable for studying the rates of flowing of the lighter and thicker colors; then, having finished this preliminary operation, the operator introduces successively into the apparatus one quart of the different colors whose degree of viscosity is required, and it is necessary only to note each time the period occupied in the flowing to establish a scale containing all the degrees of thickening in relation with the patterns, the engraving, and the stuff to be printed.

Fig. 387.



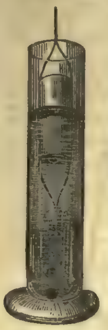
It is needless to say that, in all these valuations, it is important to keep an exact note of the temperature, since the heat, by considerably modifying the viscosity of the colors, causes considerable variations in the time of flowing.

M. HENRI SCHLUMBERGER pointed out the principal disadvantages of this apparatus, and proposes to substitute a glass funnel for the metallic cylinder when the colors are of such a nature as to corrode it.

M. DOLLFUS D'AUSSET, on the other hand, struck with the differences which occur in the duration of the flowing, according to the change of level in the column of color, conceived the idea of determining this efflux by keeping the column of liquid which presses on the orifice at a constant level, by means of a reservoir placed alongside the funnel, and in communication with it. The apparatus being thus constantly filled up to the same level, the efflux proceeds, and by weighing or measuring with exactness the quantity of color which escapes in a given time, the degree of viscosity is determined in a pretty accurate manner.

Of late years, M. IVAN SCHLUMBERGER has published an extremely simple instrument which now satisfies all the requirements of the printer in reference to this matter. It is a kind of areometer—Fig. 388—loaded with a weight for sinking into the liquid the viscosity of which it is desired to estimate, and the hollow cylinder is pierced at its lower part with an aperture of small diameter, which, allowing passage to the liquid the more readily in proportion as it is less viscid, affords the means of establishing the relative viscosity of the colors according to the time which they take to fill the vessel.

Fig. 387.



The same instrument is employed to estimate the relative value of the gums; but while it admits of determining the viscosity which they impart to a liquid, it cannot, in any case, indicate their degree of purity; for example, a senegal gum mixed with a certain quantity of British gum, which is much more mucilaginous, will always give by the viscosimeter a much thicker solution than pure gum-senegal. The fact, therefore, must not be lost sight of, that in all the valuations of the gums made by this process, the gelatinous state of these substances must be taken into consideration.

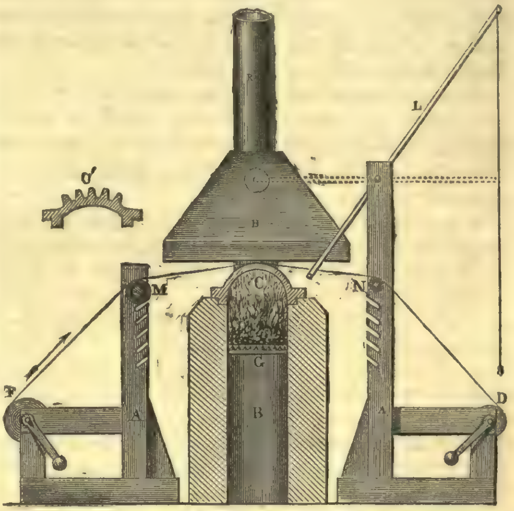
Sightenings.—When the mordant to be printed is colorless, or nearly so—as alum, red liquor, and salts of tin—it is mixed with some fugitive coloring substance, called a false color, to render the design on the cloth more perceptible, that the printer may be able to follow his work, to detect defects when they occur, and to apply a remedy to them. This addition of the false color is called *sightening*. The substances usually employed for this purpose are of several kinds: they are sometimes colored insoluble substances in a state of extreme division—such as charcoal and indigo—which are afterwards easily removed by a thorough washing; sometimes other colored preparations—such as decoctions of logwood, campeachy, Brazil wood, and even sulphate of indigo—some of which are not always got rid of with the same facility after they have served their purpose.

PREPARATION OF THE CLOTH FOR BEING PRINTED.—The object of the first operation to which cotton goods are subjected, whether intended to be afterwards printed or merely dyed, is the removal of the fibrous down or nap, and the small asperities or knots, which always exist to a greater or less extent on the surface of the cloth, however carefully manufactured by the most improved methods. This is effected by the process of *singeing*, which is generally performed on all goods about to be submitted to the operations of bleaching, and has therefore been briefly adverted to in the article on that subject.—See page 303. For goods merely intended to be dyed, the singeing may sometimes, though rarely, be dispensed with; but it is essentially necessary with a view to the printing, and therefore it has been judged best to reserve a particular description of the operation for this place.

The process of singeing may be performed by either of two different ways—one of which consists in drawing the cloth rapidly over a red-hot semi-cylindrical bar or sheet of copper, and the other in passing it quickly through a coal-gas flame. It may seem surprising to the reader, and still more to one who witnesses the process, that either of these operations can be performed on the stuff without injury to the fibre; but the truth is, that the different textile fibres are capable of supporting a pretty high temperature without being decomposed, and are, of all bodies, the worst conductors of heat, while the motion communicated to the stuff is so rapid that only the external fibres have time to be burned or singed off.

Hot-plate Singeing.—The method of singeing by passing the cloth over a red-hot surface is shown in Fig. 388, which exhibits a vertical section of a singeing furnace. B is the ash-pit; G the fire-place communicating with a vaulted horizontal flue, somewhat exceeding in length the ordinary breadth of the cloth. This flue terminates in a chimney, R, and is covered on the top with a semi-cylindrical plate, or bar, of copper or cast-iron, C, four feet in length by nine or twelve inches in breadth. Iron was formerly used, and in that case the bar was two inches or more in thickness; but preference is now given to a bar of copper, three-quarters of an inch thick, the latter being found to last much longer than the former, and to singe nearly three times as many pieces of cotton with the same consumption of fuel. With a copper bar, about fifteen hundred pieces may be singed by a ton of coals in a well arranged furnace. In some establishments, the bar is formed, as shown at C′, with five prismatic ridges. F D are winch-rollers on which the goods are wound, being previously connected together into one long piece, and fastened at both ends to other pieces of cloth, attached to the winches, so that the whole of the goods may pass over the hot plate from end to end. A A are wooden supports, bearing cylindrical brushes, M N, for raising the nap or fibres of the stuff as it passes over them; and these brushes may be raised or depressed to bring the cloth into shorter or longer contact with the plate, C. To one of the uprights, A, is fixed a lever frame, L, by which the cloth may be lifted off the bar or let down upon it at pleasure, by simply pulling its cord; and in the funnel, H, which is intended to convey the vapours produced by the ignition into the chimney, are two slots to allow the frame to be raised or depressed for this purpose.

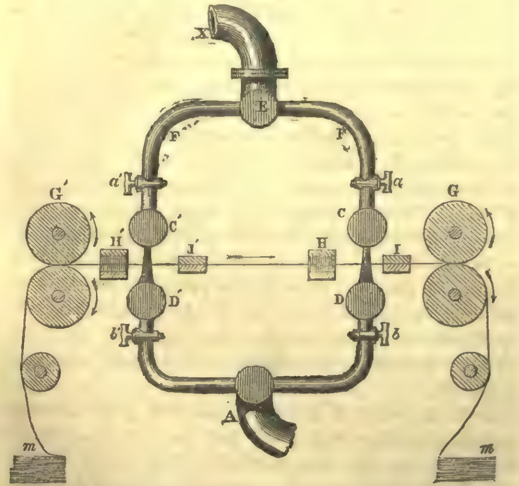
Fig. 388.



The iron or copper bar is brought to a bright red, and the goods being wound upon one of the rollers, F, and connected with the other, D, are kept in a state of suspension by the frame, L. When all is ready, they are let down upon the bar, and, at the same moment, the roller, D, which is kept wet, is turned, either by the hand or by power, and kept steadily revolving at that speed which the experience of the attendant informs him to be necessary. The cotton is generally passed over the bar three times—twice on the *face*, or the side which is to be printed, and once on that which is to be the *back*. By this operation the color of the calico becomes very similar to nankeen.

Gas Singeing.—The other method of singeing consists, as has been stated, in passing the cloth quickly through a gas-flame—a method for which a patent was obtained by Mr. SAMUEL HALL, of Basford, near Nottingham, in 1818, and which has now generally superseded the red-hot plate. The gas issues from numerous perforations through the upper surface of a horizontal tube, and the cloth to be singed is drawn rapidly over the flame by rollers. In the method first patented, the flame was drawn up through the web of cotton or other fabric by a flue leading into a common draught-chimney; but the draught not being always sufficient to draw the flame through immediately, an improvement in the apparatus was devised by Mr. HALL, and patented in 1823, which consisted in placing immediately over the gas-flame a horizontal tube, with a slit lengthways through its lower surface, which tube is placed in communication with a fan or an exhausting apparatus. This arrangement is shown in Fig. 389, where A is the principal pipe, which, by the two branches, *b b′*, distributes the gas to the two horizontal tubes, D D′. These tubes, which are seen only in vertical section, are long enough to extend to each side of the broadest webs. The perforations in their upper surface are very close to each other, and in a straight line, so that the gas forms, as it were, one long flame. Immediately over them are two other horizontal tubes, C C′, with the slits in the lower surfaces exactly corresponding to the two flames, and communicating by the branches, F F′, with the larger pipe, E X, connected with a suction-pump, or hydraulic apparatus, for exhausting the air. G G′ are two pairs of wooden rollers covered with cloth, and which, when turned, communicate to the cloth a speed of about three feet in the second. H H′ are brushes placed before the flames, assuming the course of the cloth to be, as indicated by the arrows, from *m′* to *m*; and I I′ are rubbers, covered like the rollers with fustian, to extinguish the sparks which might be carried along with the stuff. A partial vacuum is first created by some suitable apparatus in the pipes connected with C C′; the stopcocks, *b b′*, are then opened, the goods put in motion, the gas lighted, and the stopcocks, *a a′*, opened, when the flames rush into the tubes, C C′, passing sheer through the cloth, which moves, however, too rapidly to suffer damage.

Fig. 389.



Bleaching.—After being singed by one or other of these processes, the goods are bleached, except when intended for Turkey-red dyeing, or a dark ground, in which case the stuffs are treated in their natural grey state. As a general rule—that the colors of the tinctorial matters applied to tissues, whether by dyeing or printing, may appear in their purity, it is essential that the cloth be wholly freed from the foreign matters which adhere to its surface, whether imparted in the processes of spinning, weaving, *et cetera*, or else naturally adherent to the fibre of the cloth. In cotton goods, or calicoes, this is accomplished by the process of bleaching by means of chlorine; and in silk and woollen goods by the action of sulphurous acid, as fully described in the article BLEACHING.

Calendering.—When the stuff has been freed of its nap and knots by singeing, and afterwards well bleached, it must still undergo, before being printed, the operation of calendering, which has for its object to render the surface of the stuff more apt to receive the color or mordant uniformly, and to make it more easy to operate. This process has likewise been described in a previous article—see page 318—and consists essentially in passing the goods between cylinders of metal or of pasteboard, which, by subjecting them to a powerful pressure, communicate a gloss to their surface. As this operation cannot be performed without in some degree stretching the stuff both in its length and breadth, this effect has been turned to account to smooth, by a proper pressure on certain points, the parts of a web which may have undergone unequal contractions.

If the calendering is an element of success in the printing in all those cases in which the stuff is destined to receive immediately, one after another, the different colors of which a pattern is composed, it ceases to be so when it receives at one time only a part of the colors which are to figure upon it, and then has to undergo the operations of dyeing before the printing of the *re-entering colors*; for as the goods which the calendering has stretched, contract and shrink by the subsequent operations of dyeing, washing, and scouring, it often becomes very difficult to re-enter a color upon them in the very place it should occupy. This re-entering is generally termed in Lancashire *after-grounding* or *blocking-after*, the operation being performed by hand with small blocks. If the operation of calendering has been well performed, the stuff exhibits no defects, and can be brought back to its original state by a regular stretching in length and breadth, or the effects of the shrinking compensated by a proper arrangement of the engraving. When, on the contrary, the calendering has been badly performed, and the web is unequal, none of these contrivances will avail, and the printing, in a mechanical point of view, is always defective. In general, therefore, looking to these considerations alone, the printer cannot give too much attention to the choice of his goods, and to the operations which precede the printing of them, and which may give rise to an irregular contraction of the stuff.

When the goods, before being printed, have already passed into the dye-becks, and it remains to print on them re-entering colors with the block, they are still calendered, but much less than the white goods, since the dyeing, the washings, and often also the printings of the stuff having deranged the square of the pattern, the printer finds himself obliged, in order to apply his block well, and re-enter his color within the *contour* of that which is already fixed, to stretch the stuff both lengthwise and in its breadth, according to the irregular contractions it has undergone, which he would find more difficult to do if the stuff had been much calendered.

The goods which are destined for cylinder-printing ought to be, more than any others, free from knots and nap, which would act as a resist upon the delicate patterns usually printed in this manner. Nevertheless, as they should possess a certain elasticity, one must be cautious in submitting them to the calender. When the machine is not furnished with a stretching drum, they are made to slide over widening rules fixed in a bar-like apparatus, from which they proceed to be wound up on a roller, placed at the opposite point from where they arrive, and a workman has the charge of beating them carefully with a rod during this passage, to cause the dust and dirt to fall from them. It is from this roller that the stuff is unwound to pass under the engraving cylinder.

Damping.—The goods, when about to be printed, should likewise have a certain degree of dampness, to give them all the elasticity they admit of, and sufficient adhesiveness to the colors. It is doubtless from this indispensable condition that several printers, attributing to the electricity of the atmosphere an influence which it really does not exercise, are still questioning whether it be possible to attain an entire regularity in cylinder-printing. Doubtless, in a dry state of the weather, one may draw from the printing machine very powerful sparks of electricity; but all that this peculiarity proves is, that the worst conditions for successful printing then exist; that the articles and the air are then dry instead of being moist; and hence the development of electricity, far from being the cause of the accidents which supervene, is only the effect of the abnormal condition in which the process is carried on.

It is not sufficient, moreover, merely to recognise the necessity of damping the goods; it is necessary further to employ the most suitable means for attaining that end. In some cases, at the time of being rolled up, they are sprinkled over with water, or made to imbibe moisture by means of wet yarn; then they are left some hours at rest, to give the water time to spread itself uniformly. But this, and most other methods employed, present the disadvantage of wetting the goods too much at certain points and thus producing runnings, or giving rise to an unequal impression, either because the water has not penetrated equally all parts of the stuff, or because the repose of a few hours to which the goods were left on being rolled up, was sufficient for the air to dry them at the edges. In some print-works they place in front of the printing machine a steam-chest covered with a woollen cloth, on which the stuff is applied as it passes under the cylinders. This arrangement, which may be very advantageous in certain circumstances, is not, however, without danger; it may happen, in fact, that too great quantities of steam may condense, and runnings or flowings be the consequence. The most rational method, and at the same time the surest, is, undoubtedly, to make them lie in a cool and damp place, and only to submit them to the printing in a room where the air has been raised to a pretty high temperature, and further completely saturated with moisture; there is then a condensation of the moisture on the surface of the stuff, which acts in these circumstances like a decanter filled with cold water when brought into a warm chamber. At the same time, before commencing the printing of a part of the goods, the printer should previously ascertain the quantity of moisture which one of the pieces requires to be properly damped, that he may approximately calculate the weight which the roller will have when they are wound upon it. Then, when they do not contain the required quantity of moisture, he has them conveyed from a cool place into one that is warm and very moist, and by unwinding them from one roller on another, he succeeds in saturating them with the required humidity.

PRINTING-ROOMS.—Having now explained the different machines employed in printing, the preparation of the colors to fit them for being applied to the goods by these machines, and the processes to which the goods are subjected to prepare them to receive the colors, something must be said of the arrangements and atmospheric condition of the printing-rooms before proceeding to describe the details of the different processes. It is evident from what has just been stated with reference to the damping of the goods, that much of the success of the printing will depend on the kind of atmosphere in which the operations are conducted, and on other things apparently subordinate, but really of vital importance.

The operation of printing with the hand-block is performed, as already stated, in long apartments or halls, which must, above all things, be perfectly lighted, and in which are placed opposite to one another two ranges of tables, each standing in front of a window. When the general arrangement of the place permits, it is more advanageous to have the light from above, but in a somewhat oblique direction.

The dimensions of the rooms for cylinder-printing are in proportion to the number of machines employed; and their position on the premises is sometimes determined by the moving power. Some printers have deemed it important that they should be at an isolated part of the establishment, and well lighted; but in these conditions PERSOZ remarks that they have always worked less successfully than those which are placed in the neighborhood of the dye-works, and in damp situations. Doubtless light is required, but it is necessary, above all, to guard, as far as possible, against the influence of atmospheric changes, and to have the power of saturating the air with moisture at pleasure, while keeping the temperature at a constant degree. It is desirable, indeed, that in every establishment there should be certain apartments naturally damp and others naturally dry, because, according to the kinds of work performed, the printer has more chances of succeeding when the atmosphere in which the operations are conducted is independent of the care of the workmen.

At the same time, it is for the intelligent printer to determine the exact degree of heat and moisture which it is proper to give to the air of the workshop for printing particular colors on particular stuffs. The temperature is regulated by the aid of thermometers, which are suspended at the upper and lower parts of the room, and thus make known its mean temperature. As regards the humidity, this may be determined by any kind of hygrometer. One of the simplest is a cotton string, traversing the whole length of the room, and this is found to possess all the required sensibility. In the middle of the cord is suspended an iron index, shaped like a needle and rather heavy, which rises and falls according to the degree of tension communicated to the cord by the humid medium around it. There are some printers who, to keep the air constantly super-saturated with moisture, either sprinkle the floor with water, or hang up packing-cloths charged with that liquid at the upper part of the workshop, or, placing a boiler in the middle of the room, cause water to boil in it so as to emit steam or vapor. Of all these methods the most advantageous is unquestionably that which consists in hanging up wet cloths, from which the air takes only as much water as it really requires; for the use of steam gives rise to condensations more or less prejudicial to the success of the operation.

The printer who neglected these precautions would not find, in printing a single lot of the same goods, three pieces which would be exactly identical. The principal point to which he must, above all, give his attention, is the relation which exists between the temperature of the cool and damp place in which the goods have been previously lying, and that of the warm air, equally saturated with moisture, of the printing-room. The more the difference between these temperatures, the greater will be the condensation, and it is his business to make the proportion such that the color shall fix itself perfectly on the stuff without flowing.

Even when all the precautions have been taken, it is still necessary, during the printing of the first piece, to make sure, by means of a white rag pressed against the engraved roller, whether any color remains in the cavities of the engraving, which never takes place but when the stuff has not sufficient humidity, or when the air of the chamber, not being sufficiently warm and moist, instead of giving up moisture to the goods, takes it from them, or lastly, when the color does not possess that degree of viscosity necessary for printing the pattern; and then, if the engraving does not empty itself completely, while at the same time the cause of this cannot be seen either in the temperature or moisture of the room or the goods, it becomes necessary to modify the color, and to give it the viscosity which is required to make it adhere completely to the stuff.

CALICO-PRINTING PROCESSES.—There are different styles of calico-printing, each requiring different methods of manipulation and peculiar processes. At the same time, though some of these styles are perfectly distinct from each other, the divisions established by different writers are somewhat arbitrary. The following enumeration seems to include all the *principles* of the methods adopted for printing every variety of pattern on white or colored grounds—sometimes applying them singly, and sometimes combining two or more in operating on the same goods:—

1. *Madder Style*, for soluble vegetal and animal coloring matters. In this style the thickened mordants are printed on the cloth, and the colors are afterwards brought up in the dye-bath, the tinctorial matter attaching itself in a durable manner only to those parts of the cloth on which the mordant, or mordants, have been applied. It is so called from being chiefly practised with madder, to which dyestuff, however, it is by no means limited in its application.

2. *Padding Style*, for mineral colors, in which the whole surface of the calico is first imbued with a mordant by padding, and different colored figures are afterwards raised by the topical application of other mordants, joined to the action of the dye-bath; or the cloth may be first printed with one of the two saline solutions, and be afterwards padded uniformly with the other.

3. *Topical Style*, for spirit and steam colors—so called because in this style the application of the colors is purely topical, and they are printed on the cloth along with the mordant, and afterwards fixed by exposing the cloth to steam. Some colors become attached to the cloth without a mordant, and without the process of steaming, but merely by drying with exposure to the air, in which case the colors are often brilliant, but fugitive.

4. *Resist* or *Reserve Style*, by which the white cloth is first impressed with figures in a thickened substance called the *resist*, or *resist paste*, which has the effect of preventing those portions of the cloth on which it is applied from acquiring color when afterwards subjected to a cold dye, as in the indigo vat; and this paste being afterwards dissolved off in a hot bath, the effect is produced of white or colored patterns on a blue or other colored ground.

5. *Discharge Style*, which consists in applying topically to the cloth, already dyed or mordanted, a substance called the *discharger*, which has the property of decomposing or dissolving out either the coloring matter or the mordant, and thus of producing on a colored ground white or bright figures, which may be afterwards printed different colors by grounding-in with the block.

6. *China-Blue* or *Pottery Style*, which is practised only with indigo, the pigment being printed on the

cloth in its insoluble state, and dissolved into the interior of the fibre by the successive application of lime and sulphate of iron, with exposure to the air.

7. There is another style called *mandarining*, by which a yellow or orange color is communicated to the goods by exposing them to the action of nitric acid. This peculiar style is practised only on silk and woollen stuffs, and will be explained in connection with the processes employed for these fabrics.

It is evident, from their mere definitions, that these different styles do not constitute perfectly distinct processes practised separately and independently on different goods. It is by the proper combination of two or more of them that the calico-printer produces his wonderful variety of coloring on the same goods. In the madder style, which is most extensively practised, and which may be regarded as affording the most comprehensive illustration of the principles of calico-printing, and its combination with the art of dyeing, the reader will at once recognize the exact process so graphically described by PLINY, as quoted at page 567. He will also perceive that the resist and discharge styles are only available in combination with other processes, either in printing or dyeing.

In proceeding to describe the distinguishing features, and some of the most prominent applications, of these different styles, the Editor desires it to be clearly understood that nothing but a mere outline is compatible with the limits and design of this work. To enter minutely into all the processes of an art which it would require a life-time to study, and which, to be fully treated, would occupy many volumes, is here simply impossible. The Editor will therefore confine himself chiefly to principles—to that part of the subject which belongs to chemical investigation, and to such an outline of the processes as seems to be essentially necessary for illustration alone. Ample receipts for producing different colors and mordants have already been given in that part of the present article which relates to dyeing; the different coloring substances have been explained, and those who desire to be minutely acquainted with the infinite variety of receipts for calico-printing compositions, must necessarily consult the voluminous works expressly devoted to that subject. It is the Editor's object in this article, while giving a general outline of the whole subject, to devote attention chiefly to those points which are not to be found discussed in any English works on calico-printing.

I. MADDER STYLE.—This is the most important and extensively practised style, being applicable not only to the dye-stuff from which it derives its name, but to nearly all organic coloring materials which are soluble in water, and capable of forming insoluble compounds with mordants—quercitron, logwood, weld, and cochineal, for example. In this style it is not the color but the mordant that is printed on the cloth, which is then subjected to the ordinary processes of dyeing, and the colors only make their appearance in the dye-beck. In this view, the actual printing is only a small part of the process; but as the success of the whole operation depends not less upon the subsequent dyeing and fixing than upon the printing itself, these must be considered an essential part of the business of the calico-printer, in this department at least, and therefore cannot be omitted in explaining the madder style. It is intended to discuss them indeed at some length, as affording a good opportunity of investigating the action of the dung and other agents which, although previously alluded to in treating of the processes for dyeing Turkey-red, have been chiefly reserved for the present department of the subject, to receive in this place the attention which their great importance demands.

1. *Printing-on the Mordants.*—The first process in the madder style is that of printing-on the thickened mordant, which is commonly done by the cylinder machine. The kind of mordant to be applied will, of course, depend on the color which it is desired to produce in the dye-beck; and different colors or shades of color will be so produced with the same dye by printing on different mordants, or mordants of the same kind but at different strengths. Thus, to produce different shades of red on the same piece from the same madder-beck, the cloth may be printed with red liquor of any density between 3° and 25° Twaddell. The thickener usually employed for red liquor is either flour or starch, or a mixture of equal parts of the two. The proportion of the thickening is varied according to the density of the mordant required, and the fullness or delicacy of the design; on the average, a pound and a half is used for a gallon of liquid. For a weak liquor, and for a delicate figure, either British gum, roasted starch, or gum-arabic is substituted for starch or flour.

An endless variety of tints, from red to chocolate, may be obtained from the same madder-beck by mixtures of the iron and aluminous mordants in different proportions, and all shades of lilac and purple, up to black, by different strengths of the iron liquor. Patterns in black and various shades of violet and purple may be imparted to cotton cloth in the madder style by printing iron liquor and red liquor as the mordants, and afterwards dyeing in a decoction of logwood. With an aluminous mordant a beautiful orange is obtained by a mixture of decoction of cochineal and decoction of quercitron.

It is needless to observe that when different mordants, or mordants of different strengths, are to be applied simultaneously to the same piece, each must be applied to the cloth by a different block or engraved roller, according as the hand-block, perrotine, or cylinder machine is employed.

By way of example, the following is selected as the composition of one of many mordants given by PERSOZ for a common madder red:—In ten gallons of boiling water dissolve thirty-three pounds of alum, and add twenty-eight pounds of acetate of lead and 2·8 pounds of soda in crystals; to each gallon of this mixture add three quarts decoction of campeachy at a strength of two ounces per quart, twelve ounces of chloride of zinc, and thicken with 2·5 pounds of pure starch.

Another is as follows:—In ten gallons of water dissolve 35·5 pounds alum, 24·5 pounds acetate of lead, 4·2 pounds crystallized carbonate of soda, and two pounds chloride of sodium; to each gallon of this composition add 4·5 pounds nitrate of zinc at 22° Twaddell;

thicken with 2·5 pounds of starch, and *sighten* with three ounces acetate of indigo.

2. *Drying and Ageing.*—If a cloth covered with a delicate pattern were left to dry at the natural temperature of the atmosphere or that of the room, on coming out of the printing machine, it is evident that, considering its state of humidity, and that of the mordant imprinted upon it, the impression would not preserve its regularity; the mordant would spread or run, and the fine and delicate lines of the pattern would in great part disappear, while the bold and massive parts would lose all their distinctness of outline. It is important, therefore, in regard to the execution alone, that the goods pass, immediately after being printed, into a warm medium, which, by seizing on the color at its surface, may arrest its movement on the cloth, and thus maintain all the original characters of the impression. It is needless to remark that this heat must be regulated both by the nature of the tinctorial matter and mordant, and the delicacy of the pattern. But it is not only to the realization of this effect that the part performed by the heat is confined; the application of this important agent is further made with a double object; the first, altogether chemical, partly to promote the decomposition of the acetates which are generally employed as mordants, and consequently, while tending to liberate the acetic acid, to fix the bases or subsalts on the stuff; partly to resist a too rapid oxidation of the iron of the mordant which it is desirable to realize only in the pores of the stuff, and not at its surface; the second, quite mechanical, to contribute to the juxtaposition of the mordant on the fibre. It is well known, in fact, that the vegetal fibre contracts by moistening, and, on the other hand, when it is saturated with humidity, it contains much less air; for two equal portions of calico, the one dry, the other moist, boiled with water over mercury, yielded volumes of air which were to each other as one to six; now if the vapor of water produces such a displacement, it is natural to think that the color, by being substituted for it, becomes more adherent to the fibre, since no air interposes between it and the surface of the fibre.

The goods, therefore, immediately after the imprinting of the mordant, are dried by being drawn either through the hot flue—see page 699—or over a series of thin sheet-iron boxes, heated by steam. A piece of calico, twenty-eight yards long, is usually drawn through the flue in about two minutes, and is thence conducted into the *ageing* room, where it is suspended, free from folds, for one or two days, according to the nature of the mordant and the temperature. The ageing room should not be very dry, or heated above the ordinary temperature, except during winter.

This exposure of the goods to an atmosphere, which ought to have a certain degree of moisture, has for its object to aid in fixing the mordants, by giving the acetic acid time to disengage itself from its combinations, and to the oxide time to combine with the stuff. When a ferrous salt has been printed, a rapid desiccation has the effect of securing it from the action of the air, from which the thickening preserves it by hardening. The exposure to the air of a stuff charged with this mordant is therefore indispensable, as well to complete the disengagement of the acetic acid, as to make it pass into the state of a ferric salt; but it is no longer so when one prints with ferric sulphate, and knows the means of fixing it. When the goods are covered with aluminate of potassa, exposure to moist air is still indispensable, for it is necessary that the carbonic acid of the air enter into contact with the mordant; and that by combining with the potassa, the alumina be set at liberty and combine with the stuff. As regards the mordants with a base of alumina, the ageing has chiefly for its object to expel the portion of acetic acid which remains on the cloth, and to increase the proportion of aluminia which combines with the fibre; nevertheless, when the desiccation of the stuff, on coming out from the rollers, has been carried far enough to effect a complete decomposition of the mordant, if the latter was of good quality, the cloth is quite as much saturated with it as after several days exposure; the only difference observed is, that the dyes are a little less brilliant, which proceeds without doubt from the circumstance that, by exposure to the moist air, the portion of tri-aluminic sulphate which is deposited by the heat, and has not been able to yield its base to the stuff with which it was not in contact, is redissolved in favor of the octahedral alum formed, and may thus subsidiarily come to cover the mordant with a slight coating which, formed in a slower manner, is always less dull. This last consideration ought particularly to fix the attention of the printer, for to find the conditions in which a mordant returns to the state of oxide or basic salt, as hard and transparent as possible, is to ensure the formation on the stuff of a lively and brilliant color, which could not be obtained by any other process.

With reference to the hot flue, or heated chambers, through which the goods pass before proceeding to the ageing room, PERSOZ remarks that from these warm chambers are disengaged torrents of acetic acid, which pass into the air and are lost; and he asks, would it not be reasonable to collect this acid and turn it to account? Would it not be possible, for example, to force out from these chambers the air which is saturated with it, by means of one or more ventilators, and either to make it traverse a certain quantity of hydrate of lime or chalk, to convert it into acetate of lime, or to bring it into contact with sheets of copper, to make verditer and acetate of copper, or, lastly, with sheets of lead, to make ceruse, with the intervention of carbonic acid.

3. *Dunging.*—As the precipitation of the mordant in the form of an insoluble sub-salt during the hanging or ageing of the goods is never complete, it becomes necessary to remove the unprecipitated mordant from the cloth before the dyeing, otherwise a portion of the mordant, instead of remaining on the pattern, would become distributed over the whole surface of the cloth when the pieces are put into the dye-beck, and thus would cause the adherence of the dye on those parts which had not been printed. The goods, therefore, after hanging in the ageing room for a sufficient time, are drawn through the dung-becks, or else through a strong solution of dung-substitute, or sometimes, for delicate colors, through a bran-bath, whereby a part of the undecomposed mordant is separated from the cloth,

and prevented from acting on the unprinted parts, by forming an insoluble compound with the dung or substitute; the thickening paste is removed; and the mordant remaining on the cloth is *more strongly fixed*, by uniting with some of the constituents of the dung or of its substitutes.

This operation is one of the most important and most delicate in the whole process, so much so that even if all the others should be performed with the most suitable materials, and in the best conditions, the printing would not the less be a failure, if the *dunging*, as this operation is termed, had not been performed with all the necessary care. But as dung is not the only substance employed, the operation is sometimes designated by the general name of *mordant-fixing;* and according as it is performed with one or other of the different materials employed, is termed *dung-fixing*, *substitute-fixing*, *bran-fixing*, *et cetera.* The fixing of the mordants, however, is not the only effect or object of the operation, and therefore it is considered better to adhere to the old name of *dunging*, whatever be the actual ingredients employed, using that word in the same sense as the expression *madder style* is applied to a series of operations, which, although most extensively practised with madder, apply equally to some other dyes.

It is not known exactly either at what period, or with what object, dung was first used in calico-printing; it is very probable that it was the use of sheep-dung in dyeing Turkey-red that suggested the idea of *animalizing* cotton, as it was then called, to render it more fit to attract the coloring matters; but whatever may have been the motive of its introduction into the print and dyeworks, it constituted a great step in advance, especially since an intelligent use has been made of it. It appears to have been employed in the Swiss printworks so early as about the middle of last century; it was only in 1790 that it began to be turned to account in France; but it was undoubtedly used at an earlier period in this country; although, till the latter part of the last century, its application was not, as in the present day, a general practice, based upon scientific principles.

According to an analysis by M. PENOT, cow-dung contains the following ingredients:—

	Centesimally.
Woody fibre,	26·39
Albumen,	0·63
Chlorophyl,	0·28
A sweet substance,	0·93
A bitter matter,	0·74
Chloride of sodium,	0·08
Sulphate of potassa,	0·05
Sulphate of lime,	0·25
Carbonate of lime,	0·24
Phosphate of lime,	0·46
Carbonate of iron,	0·09
Silica,	0·14
Water,	69·58
Loss,	0·14
	100·00

M. MORIN's analysis assigns to it the following composition:—

	Centesimally.
Water,	70·00
Bubulin,	1·50
Biliary matter,	0·50
Green resin and fatty acid—butyric, oleic, and margaric acids,	1·52
Albumen,	0·40
Fibrous matter,	24·08
Saline matters, carbonate, phosphate, chloride, silica, ammonia, and iron,	2·00
	100·00

Several attempts were made at different times to introduce an efficient substitute for cow-dung; and M. HAUSSMANN, who studied the action of various substances with this view—that of chalk, of the bicarbonates of potassa and soda, and of soap—showed that in the heat these last substances are not fitted to replace it, seeing that by their base they attack the alumina, and that mordanted stuffs, treated with soap and bicarbonate, became unfit to attract the coloring matter of a dye-bath.

It is only within the last few years that the dung emulsion has been to some extent superseded, in many well-conducted print-works, by a solution of a mixture of phosphate of soda and phosphate of lime, known by the name of *dung-substitute*, or simply *substitute*, for the preparation of which a patent was obtained by Mr. MERCER, Mr. PRINCE, of Lowell, Masachusetts, and Mr. BLYTH. This substance is prepared by mixing sulphuric acid with bone-ash, which consists chiefly of phosphate of lime; the acid not being applied in sufficient quantity to decompose the phosphate of lime entirely, but to produce an acid phosphate, or a solution of the phosphate in free phosphoric acid. Carbonate of soda is then added to neutralize the free acid completely, and the mixture is evaporated until the residuary mass become almost dry. When the concrete thus obtained is mixed with water, it affords a solution of phosphate of soda containing some phosphate of lime; a white mud remains undissolved, consisting of sulphate, carbonate, and a little phosphate of lime, which should be carefully stirred up when the liquid is about to be used. But this preparation is not of itself an efficient substitute for all the important constituents of the dung. To supply an emollient and detergent substance in the place of the albuminous matter of the latter, it is found necessary to mix with the above liquid a solution of glue, or some other form of gelatine. The material employed for this purpose in most print works is a solution of bone-size, called *cleansing-liquor*, which is made by boiling bones in water for nearly a week, separating the fat which rises to the surface of the liquid, and evaporating the aqueous solution of gelatine until it attains a density of about 36° Twaddell. The method of applying this solution will be described afterwards.

Sometimes, on the Continent, a bath of sal-ammoniac, or of bicarbonate of soda, is substituted for the dung-emulsion; the former, in fixing an aluminous mordant, seeing that the potassa seizes on the acid, and the alumina set at liberty, not being able to dissolve by the action of the ammonia, remains on the stuff; the second, when one wishes to fix, in the cold, mordants with bases of acetate of alumina; lastly, but only when the mordant has a base of acetate of iron, ammoniacal gas is applied, which seizes on the acetic acid and sets at liberty the base imprinted on the stuff, with which it remains united in an intimate manner. An important precaution to be taken in this case to obtain the effect desired, is only to expose the printed goods to the action of this gas when the color has a certain degree of humidity; for, if it be too dry, the gum, acting as a varnish, preserves the mordant from the reach of the ammonia, and renders useless all the expenditure of manual labor, of time, and material. It is, doubtless, from not having taken this peculiarity into account, that printers have misunderstood the influence of the action of this gas in these circumstances.

The action of bran and other substances used in particular cases instead of dung, will constitute the subject of future consideration. In the meantime the details of the process will be stated, on the understanding that dung itself is the substance employed.

To explain more clearly, however, the object proposed to be effected by the operation of dunging, it may be desirable to state briefly in the first place the nature of the different substances which are found, after the ageing, on a stuff which has been printed with one or more mordants. Assuming for example that the pattern is to consist of six colors or shades; in that case six mordants have been printed—say, three with an iron base to form with the madder a lilac, a violet, or a black; two with an aluminous base, to produce a light red and a dark red; lastly, the sixth formed of a mixture of these two bases, to furnish a puce. This example is merely selected to show the variety of pattern of which the madder style admits with a limited number of ingredients; and in this case, after the printing and ageing, the following substances will be found on the goods:—1. The thickening which has been used, and which, according to its nature, is more or less soluble in water. 2. The false color, called the sightening, which may have been required in the mordant to enable the printer to follow his work, and which may consist of charcoal, indigo, infusions of Campeachy, Brazil wood, or other coloring substances, sometimes capable of removal only by chemical displacement. 3. Alumina, or hydrated oxide of iron, according to the kind of mordant. 4. Sulphate of alumina—red mordants—or a certain quantity of basic acetate—mordants of iron. 5. Cubic alum, which is re-formed by the reaction of a portion of octahedral alum on the alumina or the tribasic sulphate, which, not being in immediate contact with the stuff, is not combined with it—mordants of alumina. 6. Variable quantities of anhydrous cubic alum, the formation of which depends on the proportions of steam introduced during the desiccation of the mordants—mordants of alumina. 7. Octahedral alum in so much greater proportion as the alum employed was more acid and less thoroughly saturated by an acetate—mordants of alumina. 8. A quantity of mordant of alumina, or mordant of iron undecomposed, when the goods have not been exposed to a sufficiently high temperature after their printing, and especially when they have not been heated in a moist atmosphere.

If one could ever be sure of having fixed by the impression on the stuff, the quantity of mordant necessary to obtain the desired shade, and that, moreover, the excess of the mordant could be taken off by the water without being shifted on the white parts, it would be sufficient to wash the cloth in appropriate machines till the gum and the excess of mordant had entirely disappeared; but unfortunately this is not the case: goods printed at the same time and with the same mordants often exhibit places more or less charged with color, according as, during their circulation in the drying apparatus, certain parts have been more acted on either by a current of moist air, which has there fixed a greater quantity of mordant, or of dry air which has produced a contrary effect, and hence it becomes necessary to get rid of this inequality of tone or of shade, by forcing the mordant to combine with the stuff in the parts on which it has not been fixed. There are likewise portions of mordants which, not being in immediate contact with the stuff, and consequently not in desirable conditions for adhering to it, might get detached and deposited on the reserved parts; now, it is of great importance to prevent the blemishes which would result to the dyeing from this displacement. On the other hand, the mordants are always accompanied with variable proportions of acid, which it is indispensable to saturate to prevent their action on the parts which are fixed. Lastly, it is always required to get rid of the quantities of mordant which, not being intimately combined with the stuff, would get detached, either during or after the operations of the dyeing, and while causing a pure loss in the consumption of coloring matter, would nevertheless produce only shades more or less scratchy, due to the less colored parts, which their disappearance would leave exposed. To attain these results recourse is had to *chemical* and *mechanical* operations.

The former, which consist in passing the goods into a bath of dung or dung-substitute, heated to a suitable temperature, have for their object:—1. To set up the entire combination of the aluminous and iron subsalts, which are formed by seizing on the acid which the desiccation has not expelled. 2. To dissolve and take away from the stuff the greater part of the substances which have served to thicken and to color the mordant. 3. To separate from the stuff the parts of the mordant which are not combined with it, while preventing at the same time these parts from spreading over the surface, adhering to it, and attracting the dye.

The second operations to which the goods are subjected, and which are purely mechanical, are simply washings or scourings, perfectly similar to those which have been described in treating of bleaching, and have for their object to aid in the expulsion, not only of the soluble parts which could not be extracted from the stuff by a simple immersion in water, but further of those which are insoluble and which, not forming an essential part of the fabric itself, require to be detached from it. As these operations have been explained at length, it will be sufficient to have indicated them at present.

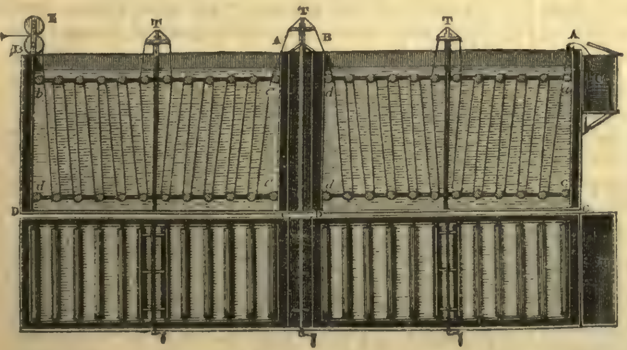
In now proceeding to describe the chemical part of the process, it will be assumed in the first place as has been stated, that cow dung is the substance employed; this recrement being found to act with effect whatever be the nature of the mordant, both because it contains alkaline and earthy phosphates and carbonates, which have the effect of determining a double decomposition on the uncombined portion of the mordant, and of precipitating it in the state of phosphate, *and also* because it contains fixed organic matters, among others albumen, which by reacting on the saline solutions form with the bases combinations so intimate that the goods cease to have any action upon them.

Dunging is usually performed in two operations and acewo different vats, whence the distinction into dunging by the cistern or square vat, and circular dunging by the wince in the common dye-beck.

The cistern or square vat is a large wooden trough of the capacity of about eight hundred to one thousand gallons, and heated by steam. In the interior of this trough are arranged movable cylinders, intended to keep in steady motion, and in a state of tension, the goods passed into the bath. These cylinders are placed parallel to each other in two rows; sometimes one row or series is placed below and the other above, so that in this case the goods sink and rise alternately in the bath; sometimes the cylinders are placed on opposite sides, and the movement of the cloth then proceeds through the whole depth of the vat, following a direction parallel to the surface of the liquor. These cylinders are either fixed to the interior sides of the vat itself, or, which is more convenient, especially for making repairs, mounted in a wooden or iron frame, which is let down into the vat and taken out at pleasure.

Fig. 390 represents the first of these arrangements, or what may be termed the vertical system; only, instead of a single vat, there are two together, A B C D, A B C D; these two vats often form only one, divided by a partition. The two troughs or compartments have for their special object to allow the printer to add in one of them matters which serve to complete or promote the dunging; thus, there are mordanted goods, as those on which discharges have been printed, which are strongly charged with acid; in that case, to saturate this acid, it is customary on the Continent to add a large proportion of chalk to the first liquor. On coming out of the first cistern, the goods pass into a bath of fresh dung; at one of the extremities of the cistern is another trough fitted with a lid, in which the goods to be dunged are enclosed, since it is indispensable to preserve them from the drops of water which might reach them, and cause so many spots upon them. At the opposite end of the same cistern, if there be only one, or of the second, if there be two, are placed two traction cylinders, E, B, which have for their object to draw the stuff and assist its movement. At the intermediate points are sometimes placed pulley-rollers, T, T, T, which, while attaining the same end, permit likewise to judge of the state of the goods during their passage; in other words, to see if they are properly stretched, if no folds have been contracted, or any rents made.

Fig. 390.



The movement of the machine is very simple: two cords are passed between each cylinder in the direction to be given to the movement, and these are attached to the end of the pieces, which are fastened together to the number of thirty or forty; then it is only necessary to turn the traction cylinders to cause these pieces to emerge from the trough, U, to dip into the dung-bath, which must have been previously brought to a given temperature, to sink, rise, and sink again in passing alternately under the rollers, *c d*, *c d*, and over the rollers, *a b*, *a b*, and to rise at last to pass between the two cylinders from which they are conducted to where they are to undergo the operations of scouring or rinsing.

Fig. 391.

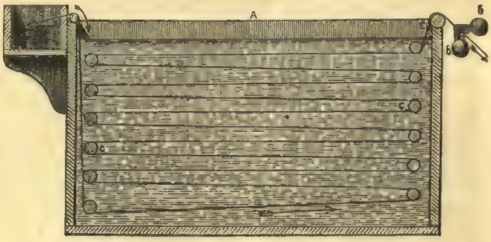


Fig. 391 represents the second arrangement above mentioned; A is a vat about ten to twelve feet in length, five or six feet in depth, and about the same breadth. On emerging from the trough D, the goods sink into the bath, till, arriving at the bottom, they rise again, following, in their circulation on the rollers, *c*, *c*, a direction almost horizontal, and arrive at last between the two traction rollers at E. On quitting these rollers, they pass at a suitable distance between two copper cylinders, *b*, *b*, pierced in the direction of their width with a row of holes through which jets of water, under a very strong pressure, are thrown upon the goods, and exercise their action in a contrary direction to that of the movement of the cloth. This rinsing of the goods on coming out of the vat greatly facilitates the operations of scouring.

When the dung-bath cannot be conveniently heated by steam, the operation is performed on the open fire in a copper boiler, in which the goods are made to circulate by means of a frame of rollers.

The goods which have undergone this first operation in the square vat are rinsed and then scoured with care, either by putting them into the dash-wheel, or by one or other of the methods described in the article on Bleaching; and these mechanical operations being finished, the second part of the dunging is proceeded with. For this purpose the pieces are connected two by two in each of the compartments of the dye-beck, described under the next process, so as to form an endless string of goods; and as this beck is divided into several compartments, there will be a proportional number of pieces in it at one time. Then, in consequence of the movement communicated to the wince at the top of the beck, the goods circulate in the bath, and the friction which takes place detaches the parts of the mordant which are not perfectly adherent to them. The more rapidly the goods circulate in this bath without tearing, the more thoroughly will they be cleaned, since in this case the particles of water drawn in come into collision with each other, and falling back determine a depression in the pores of the stuff, which empty themselves and thus get clear of the foreign matters which they contain.

On coming out of this second and last dung-bath, the goods, cleaned and scoured as after the first dunging, are ready for dyeing.

Having thus explained in a general manner the operations of dunging, it remains to give some details which are required to render the account of them complete, and to insure success.

The dung-bath into which the goods are passed, extended to their full width, in the square cistern, is usually composed of six to eight hundred gallons of water, and one hundred and fifty to one hundred and seventy pounds of dung. In France it is usual to add from three to sixty pounds of chalk, according to the nature of the dung and the quantity of acid which exists on the cloth; but in this country it is unusual to make any such addition to the dung, except in cases where the cloth contains a notable amount of free acid or acidulous salt.

As the composition of this bath goes on constantly weakening in proportion as the goods are made to circulate through it, care is taken to keep it at the proper degree of strength by adding to it from time to time a certain quantity of dung, or other substances required, according to the nature of the mordants employed. Something may be learned from the continental practice; and what must be avoided above all is, that the bath do not contract an acid reaction, which would carry off the parts of the mordant that are fixed on the stuff.

The dung-bath in which the goods are winced in the second operation is usually a little weaker. In dealing with the first or second bath, care must be taken to graduate its force according to the mordants which are made use of; otherwise a risk would be incurred of having the latter much weakened by the dissolving action which would be exerted upon them by the constituents of the dung—albumen, phosphate of soda. It is for this reason that when it is the object to obtain parcels of goods of exactly the same shade, they are never passed into a fresh bath, which would always render much weaker the tint of those which might be first dipped in it.

The choice of the dung is not a matter of indifference, for its nature or quality may exercise a certain influence upon the success of the operation. Printers have remarked that the dung of cows fed on dry fodder is always infinitely preferable to that of cows kept on green food. PERSOZ remarks that this inferiority is more especially apparent when the food of these animals consists chiefly of beet-root, so much used on the Continent. He says it has happened in several French printing establishments, that lots of goods have proved entire failures, because the dung employed proceeded from cows fed in great part on that root, the mordants being scratchy, and the shades without lustre. This difference may be explained by the small quantity of phosphate which the dung from that source is known to contain, and also by the very small quantity of fatty acids which exist in it. The same phenomena are produced when the cows have diarrhœa, and the aliment of these animals passes through the digestive apparatus without being completely digested, for then the dung contains much stuff strongly acid, which performs a part exactly contrary to what is required.

The temperature to which the bath should be heated varies from 112° to the boiling point, according to the styles of printing, the kind of mordants or rather the nature of the coloring matters which they are required to saturate, the intensity of the shades desired, and lastly the nature of the thickenings. With reference to this last point, it is evident indeed that mordants thickened with starch require, in order to be softened and disengaged from this glutinous substance, a much higher temperature than those which have been thickened with gum-senegal, with roasted starch, or any other body of great solubility in cold water, and consequently still more in warm water. A long experience has proved, moreover, that mordants intended to fix such coloring matters as those of quercitron, weld, and cochineal, seize upon these substances the better in proportion as the dunging is performed at a lower temperature, and as it is, consequently, less thoroughly saturated. It is thus that if a piece of cloth be padded or printed with mordant of alumina, and after dividing it into four parts, one of them be dipped in water, another in a dung-bath heated to 90° Fahr., the third in the same bath raised to 140°, and lastly the fourth in the same at the boiling point,—then, when all the samples have been cleaned with the same care, and after being dried are printed with a solution of thickened citric acid, it will be seen that this latter substance, which exercises its full action on the sample that was only passed into the water, has only a very slight action on the mordant dunged at 90°, a still weaker on that which was heated to 140°, and that it is almost without any effect on the sample dunged at the boiling point. Hence it is not surprising that printers dung only at a low temperature the mordants intended to be dyed in quercitron, weld, or cochineal, and that often, even for this kind, they cause the goods to be passed into a water to which has been added a small quantity of chalk.

The injurious consequences of too high a temperature of a dung-bath may proceed from another cause. Indeed, if, as theory indicates, the albumen of the dung masks the uncombined mordant which gets detached from the stuff, and renders it unfit to contract any new combination with the fabric, it is obvious that a too strong heat may annul more or less the effects of the dung by immediately precipitating the albumen by the coagulation which that substance always undergoes at about 160°.

These negative effects do not make themselves less felt when a little bicarbonate of potassa or soda has been added to the dung-bath, since these salts being decomposed by the heat, pass into the state of carbonates, and then react unfavorably on the mordants, which they always attack more or less, especially the mordants of alumina; moreover, **HAUSSMANN**, and other printers, who were not decided upon the conditions of temperature at which it is possible to employ them, came to the conclusion to reject these substances.

The duration of the immersion, or, in dunging with the cistern, the speed or rate of movement to be given to the goods, demands also serious attention. When the cistern or square vat is used, the speed communicated to the traction cylinder should be such that a piece will take from four to six minutes to pass through the bath. When dunged by wincing in the dye-beck, the temperature of the bath and the duration of the dunging for the principal styles should be nearly as follows:—

	Temperature of the bath.	Duration of immersion.
White grounds, rose and violet,..	140° or 150°,..	10 to 15 min.
———————— black and red,...	150° or 160°,..	15 to 20 —
When the patterns are charged and padded with strong mordants,..	170°,	..20 to 30 —
Mordants for half-grounds, re-entered after the dyeing,.........	140°,	..15 —

Sometimes the wincing or circular dunging is performed at a more elevated temperature, and the bath is brought to ebullition; but this practice, which may offer no disadvantage for certain kinds, presents on the contrary great disadvantages when iron and aluminous mordants have been simultaneously deposited on the stuff; for then it is not uncommon to see the ferruginous mordant carry itself over the red, however little it may be masked at the very moment of its being detached.

The manner of immersing, or of passing the goods padded or printed with mordant into the dung-bath, is also not without a great influence on the success of the operation; it is proper, therefore, to be very careful on this point. Experience proves that it ought to be done with the greatest possible rapidity and regularity; this may be concluded at least from the following experiments related by M. **DANIEL KŒCHLIN** in his memoir on dunging:—

A stuff impregnated with a strong mordant was divided into three parts, and, shortly after desiccation, they were put into the dung-bath, proceeding as follows:—the first, well stretched on a pole, was immersed suddenly, and left a minute in the bath stirring it about; the second, also stretched, was dipped slowly, so that the upper part was half a minute after the lower in being immersed in the water; the third was rolled together, dipped, and withdrawn immediately on being wetted. These three samples were scoured and dyed. The first presented a strong and full tint, the second a poor and scratchy color, the third was only slightly dyed at some parts, and exhibited a great number of blank spots.

To this fact we shall add two which are very simple and leave no doubt on the subject. Let water be applied with a pencil on any points near the end of the piece, so as not to injure its value, and it will be seen that each of the parts so touched will become a spot; or, again, let the movement of a piece through the bath be interrupted, and let the point be remarked where it reaches the level of the bath as it passes into it—a mark will be observed after the dyeing, which will correspond to that point, and will extend over the entire width of the stuff. To explain such a phenomenon, it is necessary only to understand thoroughly the object of the first operation in the dunging, which is to saturate the mordant, or to effect, upon those parts of it not disintegrated, a double decomposition which renders it unfit to combine with the goods. It will hence be understood that if a drop of water falls on the stuff, or if the progress of the piece be interrupted, the liquid penetrates in virtue of the capillary action into the pores of the stuff, and draws in, in its movement, the unfixed portions of the mordants which, by spreading on the blank parts, give them the property of attracting the coloring matters of the dye-bath. Besides this disadvantage, which is sufficiently serious in itself from the spots or blemishes it produces, the lines of the pattern, not having equal force at all points, diminish the distinctness of the impression. For these reasons it is important that the colors be of great permeability to water, and that, at the instant when the liquid has access into the pores of the stuff which is covered with it, a double decomposition be effected, the result of which is a gelatinous precipitate, which keeps the color at the very point where it has been deposited, and thus gives it the time necessary for its incorporation with the fibre, while favoring the separation of the thickening by the operations of the scouring. From these observations it will be perceived that it is essential for the thickener not to be too slow in imbibing water; otherwise, the ungumming taking place only during the scouring operations, folding-stains more or less prejudicial would be the inevitable consequence.

Even when care is taken to keep up the strength of a dung-bath, the number of pieces which can be passed through it is not unlimited; for a period arrives when the liquid, being supersaturated with oxides, would necessarily compromise the success of the operation by depositing them on the stuff.

Struck with the important part which cow-dung performs in the fixation of mordants, several chemists have endeavored to establish a theory of its operation, which is, on the whole, somewhat abstruse. **MORIN** attributed all the peculiar properties of the dung to what he termed the *bubulin*, which he discovered in it, and which he considered to be the principal agent in precipitating the metallic solutions. **PENOT**, who took a different view, tried to prove that the soluble and insoluble parts of the dung are capable of neutralizing and completely precipitating the oxides, which serve as bases to the mordants. **CAMILLE KŒCHLIN**, guided by other considerations, attributed the principal effects of the dung to the action which the fixed organic matters exert on the metallic solutions, and this scientific printer was thus led to demonstrate, contrary to the opinion both of **MORIN** and **PENOT**, that the bases of the mordants which are found in the dung-bath may exist there in solution and in variable quantity, according to the quality and the respective proportions of these mordants and of the fixed organic matters. He found, in fact, in the insoluble part of this bath, as well as in the soluble part, strong proportions of oxide, but, what is rather remarkable is this, that whilst the former or insoluble part contains quantities of iron and alumina sensibly equal, *no trace of iron appears in the soluble part.*

The plan of this work does not permit of reporting here the numerous experiments performed by CAMILLE KŒCHLIN, to ascertain the precise part performed by the constituents of the dung, and to determine the power which the latter possesses of saturating and masking the metallic oxides; the substance of his conclusions, however, may be stated as follows:—It is known that the first portions of the acetates of alumina and iron, dissolved out from the goods, will remain in solution till the collective affinities of each of these mordants are equal to the point of saturation of the soluble condition of one of them; that then the combination of the iron mordant with albumen will begin to precipitate, whilst that of alumina will remain in constant solution till that point at which its quantity, joined to that of the acetate of iron, forms a *whole* sufficient for the neutral combination of the dung. Arrived at this point, the latter will be no longer able to continue its action, and, unless reinforced by the addition of a fresh allowance, all the portions of mordant lost by the goods would be again deposited on the unprinted surface. Such is the theory propounded by PENOT, but of which, at the same time, he attributes the principal merit to PERSOZ.

Based on experiment, says the latter chemist, this theory is placed beyond doubt, but it will admit of further elucidation. It is thus that, having regard to the phosphates which the dung contains, the saturating power with which it is endowed, both in the insoluble and soluble parts, is explained to a certain extent, since experiments prove that the phosphate of lime, which is insoluble, is able of itself to effect the saturation of a mordant deposited on a stuff: perhaps, also, the printer would do well to give the preference to this phosphate over chalk for saturating the acid mordants; then, whatever excess there might be of this substance, his printings would never be injured, as often happens during the dunging in such cases, by the great quantity of chalk which must be used, and the large proportion of acetate of lime which is formed, and which, by acting as bases, more or less degrade the aluminous mordants. Moreover, by studying the composition of the dung and of the mordants which have passed into a bath of this substance, appreciable quantities of fatty acids have been detected, the presence of which cannot be without effect on the dyeing. Lastly, regarding the dunging in another point of view, one may even consider it as a true dyeing performed at the expense of the coloring matter of the dung, which maintains the oxide in that isomeric modification in which it dyes, and is then expelled by a stronger tinctorial substance, in virtue of a true displacement, when the period arrives for passing the mordanted goods into a dye-bath.

Fixing with Bran.—Formerly, bran was frequently employed instead of the dung emulsion, especially to obtain delicate shades, which the coloring matter of the dung more or less tarnishes—tender yellow, rose, and lilac, cochineal, or lively colors composed either of two coloring matters or of two mordants; gold-color, cinnamon, chocolate, carmelite, capuchin, chestnut, yolk-of-egg, orange, olive, purple, archil; or, lastly, colors for which the mordants are re-entered into grounds already dyed.

To compose the bran-bath, it is usual to mix with six hundred and fifty gallons of water about a bushel and a half of bran, which has been previously made to boil in a portion of the liquid. The operation of passing the goods through this bath is most frequently performed in the circular way in the dye-beck, but it would be more advantageous to perform it in the square vat, to avoid the running or *flowing* of the mordants. The duration of the bath is from eleven to fifteen minutes; then they are rinsed several times successively in the usual apparatus.

The action of the bran in this operation is not difficult to explain: composed essentially of alkaline and earthy phosphates, with a pretty large proportion of alumina and of gluten, it combines all the necessary qualities, as well for saturating or precipitating a mordant as for resisting the tendency of those portions which, not being intimately united to the cloth, might get detached from it, to contract a more intimate combination with the non-mordanted surfaces.

PERSOZ found, by direct experiments on bran-baths exhausted by mordanted goods, that they contained, according to the nature of the mordants, more or less considerable proportions of alumina and oxides of iron, in intimate combination with the albumen, and especially with the phosphoric acid; the bran acts, therefore, quite as much by the phosphates as by the albuminous matters which it contains. The bran, moreover, while yielding, like the dung, a certain quantity of fat on analysis, is distinguished from the dung by an acid reaction, which, however, can always be neutralized when requisite; but this neutralization is necessary only in a small number of cases.

In the present day, bran is used more particularly for brightening the colors, and bringing back to their original purity the parts of the stuff which have not been covered by mordants, but the white of which has been soiled in the dyeing. The process of brightening with bran will be explained afterwards.

Dunging with Chemical Substitutes.—The method of preparing the dung substitute in common use, consisting of solution of phosphate of soda and phosphate of lime, has been already described. The following detailed account of the mode of applying this solution to mordanted goods was communicated to Mr. PARNEL by Mr. JOHN MERCER, one of the patentees. It refers to cases in which dung is entirely dispensed with, and in which the mordant has been applied to the cloth topically, as in the madder style.

A normal solution of substitute, called *substitute liquor*, is first made by dissolving the substitute in warm water, at the rate of two pounds to the gallon. Six gallons of this liquor and two gallons of the solution of bone-size, called *cleansing liquor*—see page 711—are introduced into the cistern or square vat, which is then filled with hot water, and the pieces of cloth are passed through, by means of the rollers, at the rate of thirty yards per minute. The common dung cistern is employed in this operation, and should be capable of holding not less than six hundred gallons, with a series of rollers sufficient in number to allow the immersion of at least fifteen yards of cloth at the same time. The temperature of the solution may be the same, in general, as that of the bath in the common dunging process; for madder purples and pale reds, it should never exceed 140°, but for madder blacks and full reds it may be a little higher. This cistern requires to be frequently renewed by the addition of fresh quantities both of substitute and cleansing liquor. A gallon of the former and a quart of the latter may be added for every thirty or fifty pieces, according to the *heaviness* of the work, or the quantity and strength of the mordant on the cloth.

When removed from the first cistern, the pieces are well washed in water, after which they are winced in the weaker solution of substitute. The latter may be contained in a wince-pit or cistern, capable of holding about three hundred gallons, with which quantity of hot water there should be mixed two quarts of substitute liquor and one quart of cleansing liquor. In this liquid twenty-eight or thirty pieces are winced for twenty or twenty-five minutes, at a temperature about 10° lower than the solution first applied. The second cistern requires to be renewed by the addition of two pints of substitute liquor and one pint of cleansing liquor for every twenty-eight pieces. Both this and the first cistern should be fresh charged every morning, and emptied at night.

The only remaining operation to which the pieces are subjected, previous to being dyed, is a thorough washing in water; and if the work is heavy, they should also be passed between the squeezing rollers, and again washed.

Where the use of dung is only partially superseded by that of the substitute, the pieces are sometimes first passed through the common dung emulsion, and afterwards winced in a weak solution of substitute, mixed with cleansing liquor or glue: or the pieces may be first passed in the ordinary manner through a mixture of half the usual quantity of dung, with half the above proportions of substitute liquor and cleansing liquor, and be afterwards winced in a solution of substitute of the same strength as the second, applied as above without any dung. For madder reds, the mixture of dung and substitute seems to be more advantageous than substitute or dung alone; but for madder purples and black, a preference is given to the use of the substitute only.

The exposure to dung or substitute of cloths mordanted with alumina, should not be prolonged a sufficient time to allow of the union of the alumina with a full proportion of phosphoric acid, for coloring matters do not readily displace phosphoric acid from such a combination. The phosphate of iron, on the contrary, is easily decomposed by tinctorial matters.

Persoz remarks, that the use of this salt, or substitute, gave rise in France to some observations which may be interesting to the English printer. It was found, for example, that with the same mordants it produces hues much deeper than the dung, and this result, he states, has nothing extraordinary in it to those who understand the part performed by the phosphates. These, in fact, fix by a double decomposition the undecomposed mordant, which then becomes added to that which adheres to the stuff by the mere effect of the exposure of the goods in the hot flue, and gives a stronger tint than that which is obtained by the ordinary dunging; but it is sufficient, in order to realize the tints which one has an interest in producing, to reduce the strength of the mordant that is made use of, and to proportion it to that of the dunging salt. Some printers, while admitting its use for the mordants of iron, reject it for mordants with an aluminous base; but if it does not give the desired results when it is employed at too high a temperature, or when it contains too much phosphate of soda, it is sufficient, in the former case, to lower the temperature of the bath: in the second, to reduce the proportion of phosphate of soda. Besides, one can always increase the proportion of phosphate of lime without fear of accident.

Another double salt employed as a substitute for dung, instead of the phosphate, is the *arseniate of lime and potassa*, which is prepared in the same manner as the phosphate bath, by adding to six hundred gallons of water about twenty pounds of bi-arseniate of potassa, previously saturated with the necessary quantity of chalk, or with any other alkaline base; nevertheless, it is found, from long experience, that it is always best to employ the chalk. The composition of the bath may then be considered as consisting of arseniate of lime, which dissolves with difficulty, and arseniate of potassa, which is very soluble. It is needless to say, that in using this salt, as in ordinary dunging, or in fixing with the phosphate solution, the strength of the bath must be kept up by a suitable addition of the double arseniate, after the immersion of a certain number of pieces. The efficacy of this mixture is not difficult to understand. The arseniate of potassa, by penetrating the color, transforms the aluminous and ferruginous salts into insoluble arseniates, which remain adherent to the stuff, if they are in immediate contact with it, or detach themselves from it in the contrary case, and are then attracted by the undissolved part of the arseniate of lime, which performs the part of an absorbent body. This last, which is scarcely soluble, performs the same functions as the arseniate of potassa, although with infinitely less energy, and acts, besides, by fixing and neutralizing the excess of acid of the mordant.

It has been remarked, that these chemical substitutes for dung are only employed, with the addition of gelatine or cleansing liquor, for the purpose of preserving the blank parts of the stuff. **Persoz** maintains, as the result of different experiments made by himself, that this addition is not indispensable. He remarks, that when the strength of the mordants has been duly regulated, and the bath contains the necessary quantity of salt to determine the double decomposition, without attacking the oxide previously fixed, one is pretty sure to attain the end proposed in this operation; namely, to be able to dispense with scouring between the first and second application of the dung salt.

The reader will more clearly comprehend the influence of the phosphates and arseniates in dunging, if he reflects that the nitrates, the sulphates, the chlorides of alumina and iron, which give none of their bases to the linen and cotton stuffs on which they are applied, when merely passed into water, yield them up, on the contrary, to these stuffs when they are dipped in a bath holding in solution, and in suspension, the substitutes for dung above mentioned. These salts fix, therefore, saline compounds which by themselves do not combine with the stuff, and further prevent their *flowing* on the parts of the stuff to be reserved. Their effect, moreover, sufficiently justifies the part which has been assigned to the phosphates contained in the dung.

Gaseous ammonia has sometimes been used for the same purpose, and PERSOZ states that he saw it so applied in the establishment of Wesserling, where it was first brought into use as an occasional substitute for dunging by M. HENRI SCHLUMBERGER. It is specially appropriated to the fixing of violet mordants, for it has been remarked that the mordants of alumina exposed to the ammoniacal gas furnish brick tints.

In the application of the volatile alkali, the goods, on coming out from the printing machine, are exposed for three days to hot and moist air, as well to promote the oxidation of the mordants as to give to the color time to liquefy, and to penetrate into the pores of the stuff; they are then made to circulate in a chimney or flue, close at the top, and in which a current of ammoniacal gas is kept up to repair the loss resulting from the movement of the goods, which always imbibe a portion of it with the air, and that arising from the saturation of the acid parts of the mordant.

It appears indispensable for this operation to render the mordant as hygrometric as possible, so that an exposure of some days in the ammonia chamber may suffice to make it take up the quantity of ammonia necessary for the saturation of the acid and the precipitation of the oxide, which, when super-oxidized, loses the property of dissolving during the ulterior operations. If the color is of a drying nature, it acts in some sort the part of a reserve upon the goods, the latter alone being then charged with humidity and attracting the ammonia, so that, on passing them into the bath to remove the thickening, it will be seen that pretty strong proportions of the iron oxides dissolve in virtue of the ammonia, which, in the gaseous state, has not previously decomposed the salts. These observations explain how goods unequally desiccated in drying chambers which are not properly arranged, attract the ammoniacal gas unequally.

The *alkaline bicarbonates* are also occasionally employed to fix the mordants, and though it appears probable that one or the other of these salts may be used indifferently, nevertheless the bicarbonate of soda is that to which it is convenient to give the preference in point of economy. The solution of this salt may be made in the cistern itself in which the operation is conducted. This consists in immersing in the cold the printed goods in the cistern filled with water long enough to moisten the color, and to effect the precipitation of the base on the stuff, which has then only to be washed in order to detach the portions of oxide which do not adhere. This method of fixing is sometimes employed with advantage, especially for grounds which would be injuriously colored by the use of dung.

4. *Dyeing.*—When the goods have been submitted to the operations of dunging, either employing dung itself or one or other of the substitutes above mentioned, they are well washed, and are then ready to be exposed to the dyeing liquor. In describing this part of the process, it will be assumed that the coloring matter of madder, from which the style under consideration derives its name, is the dye employed; for although, as already stated, the same process applies to quercitron, cochineal, and some other dyes, these are managed in the same general manner, and are only distinguished by some peculiarities.

If the operations of the dyer, properly so called, were applicable in all points to the calico-printing department, it would only be necessary to refer the reader for instruction in this part of the process to what has been already said on that subject. But this is by no means the case; the calico-printer is much more straitened in his modes of procedure than the dyer, not only in this, but in some of the other styles. If he dyes stuffs of colors which fix themselves without the co-operation of mordants, he has always to combine his mordants in such a manner, that in dyeing simple grounds he shall nevertheless preserve intact the color which he has previously printed, or so that in dyeing with colors which only fix themselves with the assistance of a mordant—and most usually he has several mordants to print beside one another, or in succession to coloring matters already adherent to the stuff—he may be able to saturate individually each mordant with coloring matter without too much straining the parts that are blank or previously colored, which it is his object to reserve, and to give to the stuff on which different colors have been already fixed a new shade which will not injure their appearance.

The operation of *maddering*, or dyeing in madder, consists in exposing in suitable circumstances to a bath of madder a stuff charged with one or more mordants which have been imprinted upon it, and fixed by the operation of dunging, and in keeping it under the action of the dye till these mordants have attained the desired shade, or are *saturated*. It was formerly the practice to use, for this operation, copper boilers seated in masonry. These boilers, isolated from one another, were fixed up in a spacious chamber, and surrounded with stages which allowed the workmen to operate all round and at their upper part. Over each of them was adjusted a wince, which a workman put in motion by a handle, whilst two other workmen, placed face to face, at opposite sides of the boiler, passed the pieces by means of poles, the one from the dyestuff over the roller, the other from the roller into the dyestuff; and a third workman was charged with raising the temperature progressively. The pieces not being joined at their extremities in the manner of an endless web, it was necessary to interrupt and change the movement on arriving at one of the ends, to make them dip again into the boiler with a movement opposite to the first course. When the madder bath, gradually heated, came to boil, and the stuff had been made to stay in it for a period varying with the nature and strength of the mordants to be dyed, it was immediately passed to the washing apparatus to be rinsed, and then into the scouring machines, to be perfectly cleaned.

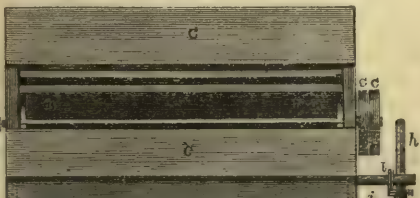
By this mode of operating, it was impossible, whatever might be the attention of the workmen, but that some parts of the stuff should come into contact with the heated sides of the boilers, and that the mordant, modified on these points, should behave differently from that which had not. To combat these injurious effects, different means were resorted to; sometimes the interior of the boilers was lined with strong packing-cloth, sometimes a basket of the same shape as the boilers was inserted within them. Afterwards, the copper boilers, usually ovoidal in form, were replaced by square troughs or vats of the same metal, from six to ten feet in length, which were surmounted with a long reel to admit of turning the pieces mechanically, and without the aid of a workman. Latterly, these copper troughs were generally replaced by wooden ones, heated by steam, which, to the advantage of a greater economy, if not in fuel, at least in manual labor, adds that of not exposing the goods to the accidents which were only too frequent with the former.

For madder-work, however, dye-becks made of iron are now generally substituted for those of wood, as it is found that, when this metal is completely covered with oxide, it exerts no injurious action on the coloring matter.

A steam-generator of sufficient power heats and supplies all the vats or becks of which a dye or print-work consists; this generator is put in communication with these troughs by a large pipe, whence tubes branch off to distribute the steam to each. On the other side, a suitable mechanism gives motion to the winces or reels placed at the upper part of each dye-beck. By means of this arrangement, a good overseer and two or three hands are sufficient to execute, with all the necessary precision, what sixty or even a hundred hands could not formerly manage.

The three annexed figures represent, namely, Fig. 392 the elevation, Fig. 393 the plan, and Fig. 394 a vertical cross-section of the dye-beck. The same letters are employed in each to indicate the same parts.

Fig. 392.



A is a wooden or iron trough, about six feet in length, four feet in width, and four or five in depth, into which the madder and the water required for a dyeing are introduced. This vessel is surmounted with a wince or reel, B, and divided in the direction of its length by a bar, *a*, in that of its width by the four bars, *b*, *b*, *b*, *b*, and thus presents five distinct compartments, into which the goods fall on quitting the reel, B. This reel, containing six or eight long wooden spars on its circumference, is furnished at one end of its axis with pulleys, *c*, *c'*, put in motion by means of a strap driven by any moving power; it is always moved by the hand in dyeing fine fabrics, as muslins, balzarines, *et cetera*. C, C, C, C, are wooden panels or lids with hinges, to be opened and shut at pleasure. The upper two open from below upward, the other two from above downward. D, E, hollow copper rollers, under which the goods pass on quitting the compartments, *b*, *b*, *b*. *f*, a tube pierced with a multitude of holes, through which the steam is introduced at pleasure by the tube, *h*, communicating with a generator. The screw-valve, *i*, affords the means of regulating the introduction of the steam into the tube, *f*. J, a pipe in communication with a reservoir of water, through which, by means of a stopcock, *g k*, which is fitted to it, one can introduce into the trough, A, the quantity of water required for the operation.

Fig. 393.

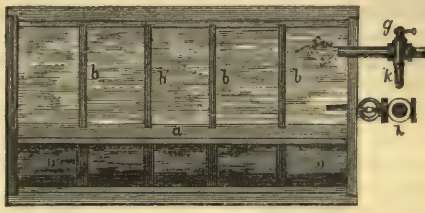
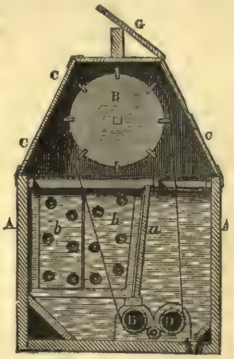


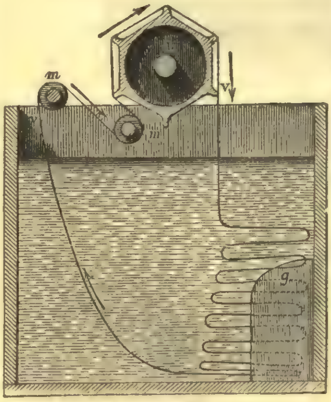
Fig. 394.



The working of this apparatus is very simple: into each of the compartments are put so many as three pieces, if their length permits, but usually two, which makes, in the case represented, ten pieces for each vat. After passing each pair of pieces over the wince, and under the tubes, D, E, they are fastened together by the ends so as to form as many endless webs as there are compartments. The movement is then given to the pulleys, C, C, and the shaft of the reel, being instantly put in motion, draws the goods in such a manner that, passing out from under the cylinders, D, they rise, pass over the reel to fall back into the compartment, *b*, corresponding to each pair, slide over the inclined plane, arrive again under the rollers, D, E, and so on during the whole operation.

It is not difficult to understand the object of placing the partition bars, *b*, *b*, *b*, *b*. If it were not for these, the pieces of the goods, by intermingling, would soon cease to obey the circulating movement which must be given them, and by remaining immovable, would expose, by their resistance, the portions of the stuff in contact with the roller, which would continue its movement, to be torn or more or less damaged, independently of the other injurious consequences which might result to the dyeing. Whatever precautions be taken, however, it will often happen that the goods, when they are too long, and when too many folds accumulate on one point, will still suffer from accidents of this description; and the workmen intrusted with this department must watch attentively to see that they keep up their movement, and hasten to disengage those which might come to a stand, as well to insure the equality of the dyeing as to prevent tearings or weakening of the stuff.

Fig. 395.



At Rouen, where an immoderate length has of late been given to the pieces, the action of the reel is assisted by the use of two traction cylinders, which, by drawing the cloth with more force, prevent it from stopping in its movement. Fig. 395 represents a transverse section of this arrangement. In this figure the parts of the vat which have been previously described are left out.

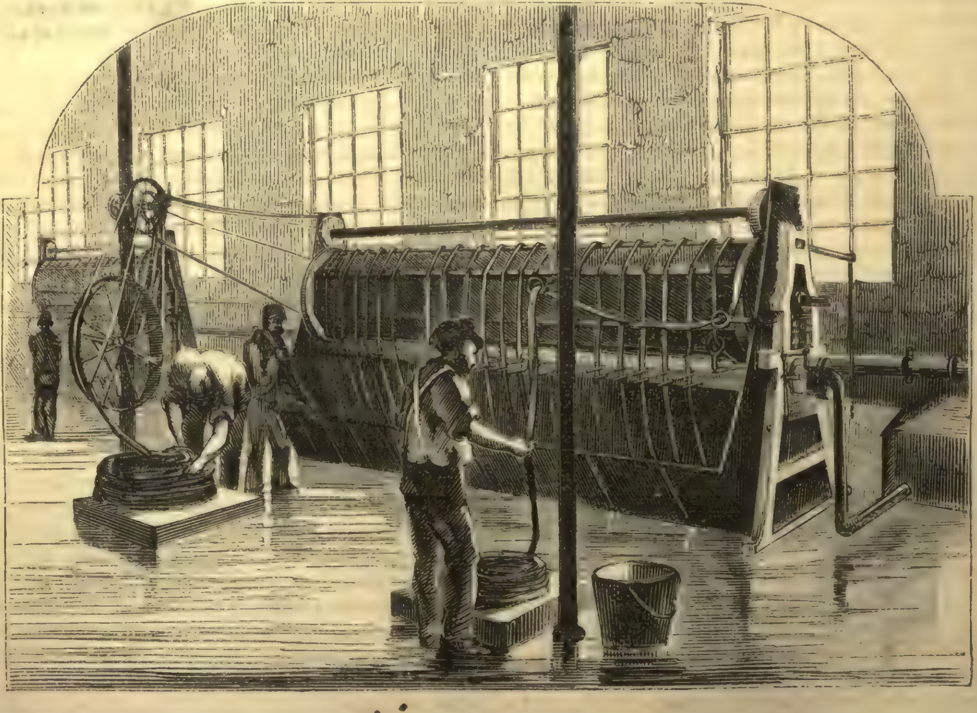
The two cylinders, *m*, *m*, parallel to the wince, L, and fixed at the two ends of the trough, serve to stretch the cloth during the circulating movement which it performs from V to V′, and oppose its remaining immovable and sliding on the sides of the apparatus.

A thermometer is placed in each trough to indicate the temperature of the bath, and to mark its progressive elevation. The subjoined engraving—Fig. 396—exhibits the ordinary dyebeck in operation.

Having thus explained the mechanical operation of the dyeing, it remains to direct attention to the most delicate part of the subject, the chemical and physical action of the different elements which compose it.

One point which it is of paramount importance to keep in mind is, that the madder, whatever be the kind employed, produces bright and fast colors only in the case of its containing chalk, or when the water that is used contains it, or, lastly, when a certain quantity of it is introduced into the dye-bath. This proposition, which was first formulated in a precise manner by J. M. Haussmann, is confirmed by all subsequent writers, among others by Persoz, H. Schlumberger, and Daniel Kœchlin. Hence it is obvious that the results will be different according as the waters employed are pure or hold lime salts in solution, or as the madder contains chalk or not; and consequently, that it is the interest of the printer to have regard to these circumstances.

Fig. 396.



Madder should be considered, first, with reference to its origin, or rather the soil in which it has been grown; secondly, its age; and, thirdly, the alterations it may have undergone. But as the properties of different madders have been already indicated, a few additional observations on the subject will be here sufficient.

It is beyond doubt, that by employing for a dye, with distilled water, madder which has been gathered in a silicious soil, as that of Alsace. for example, good colors will not be obtained; it is not less certain, that by using the same madder, along with proper proportions of chalk, or with admixture of a madder gathered in a soil essentially calcareous, like those of the Palus soils, which contain so much as ninety per cent. of carbonate of lime. one will obtain, on the contrary, dyes of the brightest description, and having the greatest capability of resistance to the agents which are had recourse to for brightening the colors, and for restoring to their natural whiteness the parts stained by the dye. Chalk is, therefore, one of the indispensable constituents of a good dye. Between the Palus madders, which contain much of it, and those of Alsace, which have not any, there is a great number of intermediate kinds; it would not be necessary to attend to these differences were it possible, without disadvantage to the dyeing, to pass beyond certain limits in the proportion of chalk employed; it would be sufficient to add this substance in excess; but, unfortunately, it is not so, for the chalk, performing the part of a base, may fix a certain quantity of coloring matter, abstract it from the dye-bath, and thus weaken the dyeing power of the madder; it is important, therefore, to proportion the addition of this saturating agent to the nature of the madders, by having regard to the calcareous quality of the water of which use is made.

As regards the age of the madders, it results from observations which are now of very old date, and the fact has been already stated, that madders of a certain age are more favorable for dyeing than madders recently gathered. According to M. H. SCHLUMBERGER, these advantages proceed from an increase of dyeing power determined by the fermentation.

These are PERSOZ'S views on the subject. For the following information the Editor has to thank Mr. JOHN MERCER:—

Madder, according to Mr. DUGALD CAMPBELL, contains a large quantity of the elements of pectic acid, which do not exist in it as such. If mixed with water at 32°, no pectic acid is dissolved out; but he found that at a temperature of 70° to 80°, it afforded large quantities of this acid, and this was the case particularly in those madders containing an excess of lime. This may be seen by mixing ground madder into a thin paste with water at 70° to 80°; in an hour or two the whole becomes a thin gelatinous mass, and, if there be much lime in it, has nearly lost all its dyeing power; for pectic acid, or more so pectate of lime, combines so strongly with the coloring matter of madder, that water will not extract it. Hence, what is called *spent madder* is produced in the dyeing; the pectic acid is quickly generated, and, uniting with the lime, is afterwards dyed, or combines with the tinctorial matter in the dyeing process. This accounts for the greater quantity of coloring matter in the decoction from Alsace madder, often being subjected to the pectic fermentation, in consequence of its containing no lime.

In dyeing with Dutch and similar madders, which have so small a quantity of alizarin fully formed, and so large a proportion of that substance principally in the yellow and orange state, the colors are more of the scarlet hue; these immatured dyes will not resist the action of soap, but they do that of bran well enough. The same may be said of garancin when made from Dutch, Naples, or Alsace madders. The fully-formed alizarin in these cases is but small in quantity, while the immatured substance is abundant. Garancin made from good old Turkey madder, which contains a large quantity of alizarin, dyes all colors as well as the madder from which it was obtained, unless the action of the acid has been too severe; but if so, it imparts the property of dyeing scarlety or rather purplish hues.

Garancin, whether made from fresh or spent madders, dyes good, full, and fast colors. Three pounds of garancin will dye more cloth than four pounds of the same substance ungarancined. Now, garancin contains no lime, although it dyes so well. The most probable explanation is, that the pectic constituents in madder, which, in the process of dyeing, are changed into pectic acid, exercise such a powerful effect on the tinctorial matter as to prevent it dyeing either fast or full hues. Many other substances act similarly when in a gelatinous state, as gum-tragacanth, *et cetera.* To see the effect of starch, for example, on coloring matters, it is sufficient to rub into bleached cotton cloth some thickish starch paste, let it dry, then steep it in some dilute coloring matter—say, cold Japan-wood-liquor—and the spot will come out loaded with coloring matter. A still more interesting experiment, to show the powerful attraction of one form of starch on coloring matter, is the following:—Add two equivalents of water to oil of vitriol, so as to form terhydrated sulphuric acid; let drops of this fall on bleached cotton cloth; at these spots the fibre will become transparent starch; steep and rinse in water till all the acid has been removed, then immerse in cold dilute Japan or logwood bath, *et cetera*, and the spots will acquire coloring matter sufficient for a full red or black, with aluminous or iron mordant, as the case may be.

Another corroboration of the injurious effect of pectic acid is the following:—It is well known that a large quantity of coloring matter is held insoluble by this acid and lime. When spent madder is steeped in cold dilute hydrochloric acid for some time, and then well washed with cold water, the product dyes weak fugitive colors, because the pectic acid is not dissolved and removed by so dilute an acid; but if it had been heated, then both the lime and pectic acid would have been removed, and it would afford rich colors.—*Mercer.*

When water is practically pure, like that which supplies some establishments, or like the water of condensation of steam-boilers, which is at present turned to account in many dyeworks, the remarks to be made on this subject have reference only to the proportion of water to be used, to the manner in which the bath should be heated, and to the temperature it ought to reach; when, on the contrary, the waters are charged with saline matters, like those which spring from tertiary soils, the printer must study them with care to apply to them the proper correctives. If charged with bicarbonate of lime only, which is very rare, their effect is to fix, in pure loss, a certain quantity of coloring matter, to prevent which different means are employed.

Occasionally the water is heated to disengage the portion of carbonic acid which constitutes the bicarbonate, and precipitates the neutral carbonate; but this process is expensive.

Often the water is saturated with a suitable proportion of sulphuric acid, or of oxalic acid, if the price of this latter is not too high. In this case a gallon of water is taken, and, by means of a standard liquor, one ascertains the quantity of the one or the other of these acids necessary to saturate the lime of the carbonate which the liquid contains; then, having established this point, the proportion of acid required by the volume of water which should serve as a dye-bath, is known at once by calculation. If the sulphuric and oxalic acids are employed here in preference to all others, it is on account of their great affinity for lime, an affinity so great, indeed, that the coloring matter which acts the part of an acid can scarcely displace them.

At times the water is saturated with a quantity of lime equal to that which exists in the bicarbonate; but this method, which should be used with great circumspection, since the least excess of lime would be sufficient to attack and dissolve the mordants of alumina, is only practicable in two cases, on account of the large amount of chalk which it generates—either when use is made of madder totally free from chalk, or when one has at disposal a large reservoir or basin in which to effect the double decomposition, and from which the water is decanted off only after remaining so long at rest that the carbonate of lime, which is formed at the expense of the elements of the bicarbonate and lime, is in great part deposited.

Sometimes caustic potassa and soda are employed, and this is the method which the greater number of printers have recourse to; sometimes, but more rarely, on account of the expense which this process incurs, barley bran is used.

When the waters contain, along with bicarbonate of lime, a certain quantity of chloride of calcium, and this is most generally the case, it is necessary to have recourse to other contrivances. When one has determined, by exact experiments, the quantity of the last-named ingredients contained in the liquid intended to be used, to the latter may be added the proportion of caustic soda or caustic potassa—experience has taught to give the preference to the latter—necessary to saturate the free carbonic acid, of which the bicarbonate is constituted. Then the alkaline carbonate which is formed, reacting on the chloride, determines a double decomposition, which has for effect to carry the carbonic acid on to the lime of the chloride, whilst the sodium or potassium remains in combination with the chlorine.

Instead of potassa and soda, one may employ with the same view a certain quantity of spent soap. The latter, by its base, saturates the acids, and, by the fatty acids which it contains, renders insoluble and precipitates the lime which the water holds in solution. This method is more sure, but also much more expensive. As the efficacy of the soap in this operation has been contested, the value of the objections urged to the intervention of this body in the operation of maddering will be explained in a future page.

To combat the effects of the lime which is found in the water, and which has the effect not only of absorbing a certain quantity of color in pure loss, but further of injuring the shades and staining the blank parts, astringent substances are likewise used, such as nut-gall, quercitron, and especially sumach. These bodies having a greater tendency to form combinations with the lime, dispute it with the coloring matter of the madder, and thus render the dyeing better and more economical, at least for certain shades.

Lastly, for certain kinds, recourse is had, with more or less success, to other substances; thus gelatin is used in the dyeing of black from logwood grounds with reserve mordant, and at one time euphorbia was employed.

When the waters contain sulphate of lime, the action of which is less hurtful than that of the chloride of the same base, they are corrected by adding a suitable proportion of carbonate of potassa or caustic potassa, according as they hold in solution sulphate only, or a mixture of that salt and bicarbonate of lime.

The magnesian salts, behaving to a certain extent like the lime salts, the same means are employed to clear the water of them.

The iron which is met with in waters has for its result, not only to occasion losses of coloring matter, but further, and which is more troublesome, to affect the shades of the madder so much, that it is impossible to obtain rose-colors with it. Now, even when the printer has assured himself by all the means at his disposal that the water which supplies his establishment is fitted for the operations of dyeing, he is liable to see it become accidentally ferruginous from two causes. If this water has torrents running into it, these may carry into it clays strongly ferruginous; but, in this case, by leaving the liquid to settle, or filtering it, one may guard against the disadvantages which would be occasioned by the presence of these substances, which always fix, in pure loss, the coloring matter of the dye-bath. On the other hand, if all the water, or a part only, runs or rests on marshy soils, or such as are impregnated with organic deposits, it may temporarily get charged with iron; for, the decomposition of the organic matters in presence of water having the effect of transforming into sulphide the iron which exists in a submerged soil, when this sulphide is formed and the level of the water sinks, an opposite effect is produced—the sulphide oxidizes, passes into the state of sulphate, or subsidiarily into that of bicarbonate, and as soon as a sudden flood takes place, the waters which again cover these lands, getting charged with those salts, transport them in solution to a distance. To correct waters of this nature, it is best to make use of a certain quantity of phosphate of potassa, which precipitates the iron in the state of a phosphate; this salt absorbs, indeed, a good part of the coloring matter, but at least does not injure the purity of the shades. There are printers who employ cream of tartar, adding about an ounce to the dye-beck. The office of this saline compound is to mask the oxides.

In many printing establishments, the waters are submitted to a filtration, which is effected by different methods—in some cases by constructing large basins, in which the water is previously subjected to a decomposition, which separates the salts from it.

Assuming the printer to have decided on the nature of the madder, the proportion of chalk to be added to it, the quality of the water, and the best corrective for it if it be not pure, the next points to be considered are the most favorable conditions for good madder-dyeing, and then the influence which may be exercised on this operation by the different agents that may intervene.

Is it proper, after mixing the madder with water, to leave it to macerate during a certain time before proceeding with the dyeing? From an Avignon madder, macerated at 32°, and then filtered, a liquor strongly colored was obtained, which, when heated in the ordinary manner, dyed the mordanted samples which were dipped into it pretty well; on the contrary, this same root, macerated in a water heated to 86°, yielded, on being filtered, only a liquor which scarcely possessed the property of dyeing. On the other hand, the madders of Alsace, in the same conditions of temperature, yielded infusions almost equally rich in coloring principle. The following is a table of the results which M. HENRI SCHLUMBERGER established with reference to this question, by macerating separately, during fifteen minutes, forty-six grammes—seven hundred and thirteen grains—of Avignon madder, and the same quantity of Alsace madder in 1·5 litres, or one-third of a gallon of water, at different temperatures:—

Temperature at which the maceration took place	Intensity of the shade obtained expressed in weights of madder.	
	Avignon madder.	Alsace madder.
32° temperature,	......6 grammes,	......9 grammes.
54° "	......2 "	......7 "
86° "	......1 "	......5 "
122° "	......2 "	......6 "

These experiments prove that the maceration of the madder in warm water has nothing but a prejudicial effect.

It has likewise been established that the macerations of the madder are favorable only in so far as this root undergoes a fermentation which has for its result to effect the destruction of the foreign ingredients which accompany it, and by setting at liberty the coloring matter, to render it more apt for the dyeing; but as no one has yet succeeded in stating the precise conditions in which this molecular change would be brought about in a regular manner, it has not hitherto been possible to make a practical application of this fact demonstrated in the laboratories of chemists.

From these experiments there follows, in a practical point of view, this consequence, that in proceeding to the dyeing, the madder and chalk should be mixed with water, incorporating the powder with the liquid as thoroughly as possible. For this purpose it is best to begin by wetting the madder with a small quantity of water; then, when it is well divided, and the knots or clots have completely disappeared, the rest of the liquid is added.

As regards the quantity of madder to employ for dyeing a limited number of pieces, it is difficult to determine this in an absolute manner: it varies, first, according to the quality of the madders; second, according to that of the waters; third, according to the kind of patterns, which, as they are more or less charged with mordant, consume more or less coloring matter; fourth, according to the manner in which the mordanted goods have been dunged and scoured; for when this operation has been imperfect, the portions of mordant which were not properly fixed on the stuff get detached from it, and yet absorb coloring matter; fifth, according to the modes of brightening or bleaching which have succeeded to the dyeing, and which more or less degrade the coloring matters fixed on the stuff by the mordants; sixth, according to the degree of temperature at which the dyeing is performed, because the kinds which require a low temperature demand a larger proportion of madder than those whose shade stands a higher temperature; seventh, according to the nature of the goods, for a mordanted jaconet, muslin, or light calico, requires less madder than strong and close calicoes, which fix a proportionally larger quantity of mordant.

The quantity of water which should be employed in a maddering is a point of not less importance, since the proportions of this liquid more or less modify the dyeing power of the same madder; but it is for the printer to regulate these quantities according to the quality of his water, and the conditions in which it operates, for unfortunately the data hitherto furnished in reference to this matter present too little agreement among themselves to be depended on.

In the next place, is it a matter of indifference to immerse the pieces dry or moist, cold or warm, into the dye-bath? With a little attention one must be convinced that it is more advantageous to introduce them into it dry than damp; if the color penetrates less equally at the outset, it fixes itself more rapidly. As regards the second part of the question, which many persons may consider an idle one, all the other circumstances being equal, there is a decided saving of madder by introducing the goods warm into a dye-bath, and the saving is still greater when one makes them pass directly from over a jet of dry steam into the bath. This difference is explained by the consideration, that the air expelled by the heat from the pores of the stuff, allows the colored liquid a freer access to them, by the partial vacuum which is produced at the moment of immersion.

With regard to the exact temperature at which the goods and the madder should be introduced into the water, an able anonymous German writer has shown that the most favorable temperature for dyeing is 120°; that at this temperature one obtains a result of + 31 of dyeing effect, whereas at 190° one obtains with the same madder only — 31, a difference of 62 per cent. Lower, and especially higher temperatures always give, according to the same authority, less favorable results. These experiments have been varied and confirmed, in all their essential points, by M. H. SCHLUMBERGER, who dyed for two hours, beginning with temperatures comprised between 32° and 212°, and always bringing the baths to ebullition, equal samples with the same weights of madder, and the same volumes of water. The results were as follow:—

Temperature of the water at the beginning of the dyeing.	Expression of the shade obtained in positive or negative quantities of madder. The normal shade = 0.
32° temperature,	— 26 per cent.
68° "	— 17 "
104° "	0 "
140° "	+ 17 "
176° "	— 17 "
212° "	— 50 "

According to these results, there would be a great economy in entering upon the dyeing at 120° or 140°, since it is the most favorable degree of temperature; but one cannot apply these data to practical operations, first, because there are shades, like madder rose, which dye only at much lower temperatures; next, because a too rapid dyeing is rarely uniform in its results; and, lastly, because colors at temperatures above 70°, 80°, and 100°, do not so well resist the operations of brightening, since, in this case, the coloring matter, which precipitates with too much energy on the stuff, being immediately absorbed by the surface of the mordant, with which it forms as it were a crust, does not penetrate the interior of the latter, and consequently the greater part of it disappears in the operations which follow the dyeing.

A point to which too much attention cannot be given is, that it is always of importance to raise progressively the temperature of a madder bath, or at least to maintain it stationary, for experience has shown that this temperature cannot be let down, to be raised again, without suffering great losses of coloring matter. Thus M. **Henri Schlumberger** showed that a madder bath, after being brought to 130°, cooled again to 90°, heated anew to 160°, again cooled to 100°, and finally brought to ebullition, had lost 40 per cent. of its dyeing power.

Lastly, to abstract the whole of the dyeing substance from a madder, may the dyeing operation be prolonged for a longer or shorter time, or does it answer best to limit the duration of the maddering, by raising the bath during a certain lapse of time to an elevated temperature? The anonymous authority to whom reference has been made, affirms that the duration of a maddering should be limited; that it should be accomplished in the space of two hours, taking the precaution to raise the bath progressively to ebullition; that beyond these limits there is loss of coloring matter, and, likewise, if the dyeing is prolonged, of labor, fuel, and time. M. **Henri Schlumberger**, who is not of this opinion, and who has the results of experience in his favor, has shown that the duration of a maddering may be prolonged during four or five hours, provided the temperature of the bath is kept up at the same degree, or progressively raised. The subjoined table exhibits a summary of the experiments which he made on this subject:—

Duration of the dyeing.	Duration of the boiling.	Results of the dyeing expressed in positive and negative quantities of madder.
½ hour,	5 minutes,	— 25 per cent.
1 "	10 "	— 15 "
2 "	15 "	0 "
3 "	30 "	0 "
4 hours,	30 minutes,	+ 8 per cent.
5 "	40 "	+ 8 "
6 "	40 "	+ 8 "
7 "	40 "	+ 17 "
8 "	60 "	+ 17 "

These experiments establish in a convincing manner, that by prolonging a dyeing, far from experiencing a loss, one derives on the contrary greater advantage from the coloring matter; at the same time, it would be an error to conclude that it is proper in all cases to prolong the maddering; it must first be considered whether the economy in madder is compensated by the expenses of labour, fuel, and time. Lastly, another fact should be taken into consideration, namely, it seems a general rule that the colors due to a prolonged dyeing do not generally resist the brightenings so well. It has been shown that a too rapid dyeing, or one performed in too short a time, is defective, inasmuch as that the coloring matter, depositing itself at the surface of the mordant, does not reach the centre; a too prolonged dyeing is not less so, seeing that in this case the foreign substances in the coloring matter, which always more or less attack the mordants, produce on them the effect of actual discharges.

To ascertain if it be necessary to bring the dye-bath to ebullition, in order to abstract from it the maximum of coloring matter, M. **Henri Schlumberger** performed several dyeings at different temperatures, both with Avignon and Alsace madder, prolonging the duration of a certain number of these dyeings for three hours, and others for eight; the following table contains the results of his operations:—

Temperatures at which the dyeings were		Results of dyeings of three hours' duration.		Results of dyeings of eight hours' duration.	
Commenced.	Terminated.	Avignon madder.	Alsace madder.	Avignon madder.	Alsace madder.
		Per cent.	Per cent.	Per cent.	Per cent.
at 32° ..	at 32°	— 95	— 95	— 95	— 95
50° ..	50°	— 96	— 92	— 89	— 89
68° ..	68°	— 89	— 79	— 70	— 79
86° ..	86°	— 79	— 70	— 30	— 46
104° ..	104°	— 55	— 58	0	— 22
104° ..	122°	— 38	— 46	+ 17	— 14
104° ..	140°	— 22	— 38	+ 17	— 6
104° ..	158°	— 14	— 24	+ 17	0
104° ..	176°	— 6	— 6	+ 17	+ 8
104° ..	203°	0	0	+ 17	+ 8
104°	Ebullition.	+ 8	+ 6	+ 17	+ 8

From this table the following conclusions may be drawn:—

1st. That, for dyeings of short duration, the temperature of the bath must be elevated, if one wishes to extract from the madder the maximum of coloring matter, since, for dyeings with Avignon and Alsace madder, of three hours' duration, the normal shade is obtained only at 203°; that below this there is loss, and that an augmentation is obtained only by ebullition.

2d. That, on the contrary, for prolonged dyeings, it is not necessary to raise the temperature so high, since a bath heated from 104° to 122° during the space of eight hours, gives the same results as if it were at ebullition. This point is not without importance, for the necessity of always raising a madder bath to the boiling point, in order to obtain from it the maximum of coloring matter, would be attended with serious disadvantages.

3d. That there is loss of a large quantity of coloring matter in dyeings under 104°; but that this loss goes on diminishing in proportion as the temperature approaches that point, or nearly the point at which the maddering is most effectually done. It is to be remarked, nevertheless, that certain shades, such as pale rose-color, can only be obtained at very low temperatures; in that case care is taken to utilize for other styles the strong proportion of coloring matter which the residue of the maddering bath still contains.

4th. That from 104° and upward, the Alsace madder, all other circumstances being equal, requires, in order to yield its coloring matter, a higher temperature than Avignon madder; that the contrary takes place at temperatures under 104°.

With regard to the influence of the air, it cannot be doubted that it exercises an action on the madder, for, in contact with a fresh bath of this root, it reddens it and precipitates the coloring matter from it; but is this action favorable or otherwise to the dyeing, both in regard to the development of dyeing power and the durability of the shade? In the knowledge of the fact that Alsace madder, though incapable by itself of giving good and durable shades, acquires, along with this property, a greater richness when it has been long in contact with the air, one is led to decide in the affirmative; nevertheless, a difference of opinion still exists on this point.

The next subject to be considered is the influence exercised on the dyeing by the foreign bodies which may be introduced into a madder bath. M. HENRI SCHLUMBERGER was the first who turned his attention to this question. Having found that the absence of chalk is the only character which distinguishes the Alsace madder from that of Avignon, and knowing, moreover, from the experiments of HAUSSMANN, that this carbonate is indispensable to a good dyeing, he wished to see if there were other bodies capable of giving to the Alsace madder the property of dyeing like the Avignon madder; that is to say, so as to stand the clearing processes. The experiments to which he addressed himself prove, that if there are some substances which, to a certain extent, are capable of replacing the chalk, as phosphate of lime for example, there are others, such as the oxide and carbonate of copper, which exercise an action so unfavorable as to frustrate the dyeing.

Subsequently to the publication of HAUSSMANN'S results, the anonymous author already cited addressed, in 1835, to the Industrial Society of Mulhouse, a memoir entitled, *Researches and Results on the Means of Extracting, by Dyeing, the Greatest Quantity of Coloring Matter from Madder*, in which he examines successively the action of a multitude of substances on a madder bath. Although the results obtained by this observer have not all been confirmed, there are a certain number of them which present sufficient interest to make it desirable to reproduce them here. To establish these results, he conceived the happy idea of forming, with determinate proportions of pure madder, two very extended scales, with which he might compare the products of his different dyeings. To form these scales, he took four equal pieces of cloth, two of which he padded with mordants of alumina, the one very strong, the other very weak; the other two with mordants of iron, corresponding in strength and weakness to the first two. Setting out with a madder bath extremely weak, he successively dyed equal portions of cloth padded with weak mordants, with greater and greater proportions of madder, till he had found the weight of its powder necessary for the saturation of the mordant. After thus obtaining gradations of tints corresponding to proportional weights of madder, he repeated the same operations on strong mordants, but beginning with a proportion of madder just above that which he would have had to employ to arrive at the saturation of the weaker mordants, and he established a new scale of tints, equally corresponding to known weights of madder, and which, joined to the first, gave him an uninterrupted scale of shades, each tone of which corresponded to known proportions of madder. Then, by operating, for all his further experiments, on similar surfaces of cloth mordanted in the same manner, and on a quantity of madder equal to the mean weight of the two extreme tones of the scale, he would evidently find that the shade of a dyeing made with a constant weight of madder of the same quality would be equal either to that of the normal scale, which is represented by 0, or zero, or to that which would result from the use of a stronger or weaker proportion of madder, represented in that case by the sign +, or the sign —, followed by the figure which indicates the quantity of the dyeing substance.

Such is a condensed statement of the ingenious process which he followed to procure the means of determining the influence exerted by a great number of foreign bodies on a dye-bath. The different tables in which he embodied the results of his experiments will now be given, following each with the reflections which it suggests:—

Effects produced by ammonia and alkaline compounds on dye-baths.

				Per cent.
1-60th	of the weight of the madder		in carbonate of potassa gives	— 5
1-60th	Do.	do.	in carbonate of soda,	— 8
1-60th	Do.	do.	quick lime,	—30
1-60th	Do.	do.	carbonate of lime,	—46
1-20th	Do.	do.	ammonia,	— 5
1-60th	Do.	do.	ammonia,	—28

This table shows that alkalies and alkaline salts, when added to a madder bath, diminish its tinctorial power.

Effects produced by the earthy and metallic oxides on dye-baths.

				Per cent.
1-120th	of the weight of madder		in magnesia gives	— 16
1-60th	Do.	do.	in carbonate of magnesia,	— 13
1-60th	Do.	do.	oxide of lead,	— 11
1-60th	Do.	do.	oxide of zinc,	— 26

If the author had studied in the same manner, says PERSOZ, all the metallic oxides, he would have found, with M. HENRI SCHLUMBERGER, that several of these bodies, especially the oxide, hydrate, and carbonate of copper, added, even in small proportions, to a dye-bath completely destroy its power.

Effects produced by the acids on dye-baths.

				Per cent
1-120th	of the weight of the madder		in sulphuric acid at 162° Twaddell produces	— 22
1-120th	Do.	do.	in hydrochloric acid at 36°,	— 20
1-120th	Do.	do.	nitric acid at 66°,	— 9
1-120th	Do.	do.	tartaric acid,	— 23
1-120th	Do.	do.	oxalic acid,	— 17
1-120th	Do.	do.	citric acid,	— 22
1-60th	Do.	do.	vinegar,	— 6
1-120th	Do.	do.	boric acid,	— 7
1-120th	Do.	do.	benzoic acid,	+ 21
1-60th	Do.	do.	arsenious acid,	+ 6
1-120th	Do.	do.	phosphoric acid,	+ 8

The presence of almost all the acids is, therefore, according to this table, unfavorable to a madder dyeing; the benzoic, arsenious, and phosphoric acids make the only exceptions, since, with these agents, the madder furnishes richer or more intense hues. This result, generally admitted as regards the arsenious and phosphoric acids, is contested in the case of the benzoic acid. It will not appear surprising that the acids should be hurtful to a dyeing, if one considers the part performed by the coloring matters, which, while themselves acting as acids, but with feebler power, are displaced by them, and become in their presence insoluble, or scarcely soluble, and consequently unfitted to combine with the bases; but even this very part which they perform enables one to conceive how the acids which are regarded as exerting a pernicious action on the dyeing—sulphuric and oxalic acids, for example—may nevertheless, in certain circumstances, become useful auxiliaries. If a dyeing, for instance, has been performed with a Palus madder and distilled water, or with Alsace madder and chalk, and the bath has been so much exhausted as to yield nothing more to the mordants, a suitable addition of sulphuric or oxalic acid will, by giving it a certain degree of energy, have the effect of rendering this bath still capable of dyeing. In fact, the phenomenon which takes place during the maddering is as follows: a portion of the tinctorial matter becomes fixed on the lime, and when once engaged in such a combination, becomes unfit to dye; but if the acids above mentioned be interposed, this combination is destroyed, and the coloring matter, set at liberty, exerts its action on the mordants. If, however, the acid employed should be in such quantity as to predominate, the coloring matter would produce no further effect, either because it would become insoluble, or because, naturally weaker, it would not be able to dispute with the acid the power of combining with the mordants. This experiment, which PERSOZ repeated several times, both with oxalic and sulphuric acid, always succeeded, by taking care to add to the bath only a small part at a time of the quantity of acid judged necessary, and to withdraw at each addition the sample of mordanted cloth which was in that bath.

Effects produced by saline compounds on dye-baths.

				Per cent.
1-60th	of the weight of the madder		in sulphate of potassa yields	+ 25
1-60th	Do.	do.	in sulphate of soda,	— 21
1-60th	Do.	do.	chloride of sodium,	— 9
1-60th	Do.	do.	nitrate of soda,	— 10
1-60th	Do.	do.	tartrate of potassa,	— 31
1-60th	Do.	do.	oxalate of potassa,	— 29
1-60th	of the weight of the madder		in acetate of potassa, yields	— 7
1-60th	Do.	do.	in acetate of soda,	— 10
1-60th	Do.	do.	chromate ot potassa,	+ 26
1-60th	Do.	do.	bichromate of potassa,	+ 28
1-60th	Do.	do.	arseniate of potassa,	+ ·5
1-60th	Do.	do.	chloride of calcium,	— 28
1-60th	Do.	do.	sulphate of lime,	+ 7
1-60th	Do.	do.	phosphate of lime,	+ 16
1-30th	Do.	do.	moist phosphate of lime	+ 42
1-60th	Do.	do.	acetate of lead,	— 34
1-60th	Do.	do.	alum,	— 40
1-60th	Do.	do.	soap,	+ 18

It is very remarkable that two compounds so like each other as the sulphates of potassa and soda exercise an action so dissimilar, that there should be a difference of forty-six per cent. in favor of the former. If it were only required to explain why the sulphate of soda is hurtful, whilst the sulphate of potassa is not so, the cause of it might be found in the power which the former possesses of forming combinations with the water, which it disputes with the coloring matter, and consequently the latter, without a suitable vehicle, becomes unfit to accomplish its action; but there is something more required to account for the positive part performed by the sulphate of potassa, which is still a mystery. Whatever it be, it is not the less true that a long experience has convinced dyers of the necessity of employing potassa, and not soda, to correct the calcareous waters intended to be used in maddering, which proves, further, that the salts of potassium—chloride and sulphate—which are formed and remain in solution in these waters, are more favorable than the corresponding salts of soda.

Of all the saline compounds employed, the hydrated phosphate of lime is that which produces the most effect; doubtless it is to the portion of phosphoric acid in its composition that it owes in part this property.

The soap exercises also a favorable influence, as the following experiment attests:—When a madder bath is exhausted by the dyeing of mordanted stuffs, one can always, by adding to it a certain quantity of this compound, dye, though in weaker tones, fresh goods, especially when they are mordanted for violets. In such circumstances the dyeing is effected without the blank parts being stained.

Several dyers make use of soap, with the view of utilizing their residues of madder, and it has been affirmed that soap added to an exhausted bath effects an economy of one-fourth to one-third of the coloring matter. M. HENRI SCHLUMBERGER, having undertaken some experiments in connection with this subject, alleged that an addition of soap to an exhausted dye-bath neither renders the coloring matter soluble nor fit for dyeing; that it is, on the contrary, always hurtful, and is consequently far from increasing the extraction of the tinctorial matter. To explain an opinion so different from the general belief, it must be assumed either that he operated on a soap of peculiar quality, or that he employed it in peculiar proportions, for soap must necessarily cause the compound of coloring matter and lime which exists in the residue of a maddering to undergo a double decomposition, the result of which is the production of an insoluble calcareous soap, and of a combination of the coloring principle with the alkaline base of the soap, which, momentarily soluble, yields its coloring matter to the mordant at the instant of its being destroyed. This so natural explanation is the only one which can account for the part performed by the soap in the bleaching of the unmordanted parts of a stuff, which are more or less stained by a portion of the tinctorial principle combined with the lime on passing into a dye-bath.

Effects produced by vegetal and animal substances on dye-baths.

			Per cent.
1-10th	of the weight of the madder	in wheat bran yields..	— 17
1-10th	Do.	in wheat bran mixed with boiling water,	— 8
1-30th	Do.	wheat flour,	— 8
1-30th	Do.	oatmeal,	— ¼
1-30th	Do.	starch,	— 27
1-30th	Do.	salep,	— 13
1-30th	Do.	gum arabic,	— 10
1-30th	Do.	gum tragacanth,	— 18
1-30th	Do.	sugar,	+ 28
1-60th	Do.	salicin,	— 14
1-30th	Do.	linseed meal,	— 9
1-30th	Do.	starch-gum—roasted starch,	+ 13
1-30th	Do.	barleymeal with bran,	— 13
1-30th	Do.	peasemeal with bran,	— 17
1-30th	Do.	sumach,	— 5
1-30th	Do.	pulverized gall-nut,	+ 24
1-15th	Do.	do.	+ 34
1-30th	Do.	ratanhia,	— 16
1-30th	Do.	catechu,	+ 11
1-30th	Do.	oak-bark,	+ 25
1-30th	Do.	willow-bark,	+ 13
1 30th	Do.	pine-bark,	+ 17
1-30th	Do.	bark of pomegranate,	+ 53
1-30th	Do.	fir-bark,	+ 13
1-30th	Do.	oak saw-dust,	— 14
1-30th	Do.	alder saw-dust,	— 21
1-30th	Do.	quercitron,	+ 27
1-30th	Do.	quassia,	+ 42
1-30th	Do.	marsh clover,	+ 32
1-30th	Do.	aloes,	0
1-30th	Do.	ox-blood,	+ 39
1-30th	Do.	albumen,	+ 4
1-30th	Do.	milk,	+ 15
1-30th	Do.	ox-gall,	— ⅓
1-30th	Do.	cow-dung,	— ½
1-30th	Do.	strong glue—gelatin,	+ 4
1-30th	Do.	strong glue dissolved in warm water,	— ¾

Several of the results recorded in this table are only the confirmation of facts long known by experience. It shows that the advantage derived from ox-blood, which is always used in Turkey-red dyeing, is + 29 per cent. The astringent substances formerly in constant use figure in it also with positive signs; and it may be remarked, that the action of these substances must not be confounded with that of the acids and of the saline compounds which have been specified, seeing that they intervene directly in the dyeing by being added to the coloring matter of the madder. Thus a mordanted cloth, dyed in a madder-bath to which quercitron or sumach powder has been added, takes a red color slightly orange, which alone proves that a certain quantity of the yellow coloring matter is fixed to the mordant of alumina; but let this cloth be covered with a mordant of iron, and one can no longer doubt that an astringent substance adheres to it, for the red part, instead of becoming puce, will become black, in consequence of the reaction which will be established between the tannin and the oxide of iron.

One may likewise see in this table the sensibly negative effect of the cow-dung, which some printers are in the habit of adding to their maddering; and lastly, that it is not indifferent to employ, either cold or in a dissolved state, the gelatin of which such frequent use is made.

Effects produced by the sulphides on madder-baths.

				Per cent
1-30th	of the weight of madder		in tersulphide of arsenic—orpiment—yields	+ 36
1-30th	Do.	do.	in bisulphide of arsenic—realgar—gives.......	+ 3
1-60th	Do.	do.	in sulphide of potassium,..	— 20
1-30th	Do.	do.	in sulphide of calcium,...	— ¼

This table shows the favorable action of the tersulphide of arsenic—orpiment—in dyeing. There is nothing surprising in this result, especially when the maddering is performed at ebullition, because at this temperature the tersulphide, decomposed by water, is transformed into sulphide of hydrogen, which is disengaged, and into arsenious acid, which remains in solution, as shown in the following equation:—

$$\underbrace{As\,S_3}_{\text{Tersulphide of arsenic.}} + \underbrace{3\,HO}_{\text{Water.}} = \underbrace{As\,O_3}_{\text{Arsenious acid.}} + \underbrace{3\,HS}_{\text{Sulphide of hydrogen.}}$$

Now, as this last has a sufficiently decided positive power in the maddering, it is natural that the compound which gives rise to it in the very circumstances of the operation should be possessed of the same property.

Having passed in review the bodies which have some influence on madder dyeing, it now remains to explain, if possible, the action which they exert.

That which has the most remarkable effect is unquestionably the chalk, which gives to the Alsace madder a power that it does not possess by itself. The specific characters of this madder are such that some dyers, still refusing to admit the identity of its coloring matter with that of the Avignon madder, maintain that the dyes which it forms do not stand the clearing processes, and that it cannot be used for certain styles.

When Messrs. DANIEL KŒCHLIN, H. SCHLUMBERGER, and PERSOZ, endeavored to account for the important part performed by the lime in the operation of maddering, a twofold question presented itself to them:—Has this body no other effect than to neutralize an acid, the existence of which has been more than once pointed out in madder, or does it become an integral part of the colored combination which is effected on the stuff itself?

The first of these modes of viewing the action of the chalk is that which generally prevailed formerly, without any other reason than the simple fact of the use which is made of it; but if the chalk were in this case only a saturating substance, every other similar compound ought to conduct to the same result. Now, it is demonstrated that a great number of bodies endowed with at least an equal power of saturation, not only communicate no permanence to the madder, but even become an obstacle to its fixation on the mordants, and occasion great losses of coloring matter. In fact, the phosphate of lime, the carbonates of potassa and soda, replace, to a certain extent, the chalk; but it is natural to inquire, on the one hand, whether the phosphate does not yield to the bath a certain quantity of its base; and, on the other hand, whether the carbonates, by the double decomposition which they produce in all the soluble and insoluble salts, have not equally the effect of indirectly bringing the chalk in contact with the madder?

It was from these considerations, and guided, moreover, by others of a different nature, that the above-named chemists directed their labors, and examined whether the chalk does not contract an intimate combination with the alumina and the coloring matter. For this purpose, after having purified some yards of calico by reiterated treatments with acids, they padded them, some with iron mordant, others with alumina mordant, and dyed them in baths of distilled water and Alsace madder in suitable proportions, with and without the addition of chalk. Having then burned and incinerated the samples so dyed, they submitted their ashes to analysis, and found that those of the stuffs dyed with addition of chalk contained in ten square inches of burned cloth 2·5 grains of lime, those of the cloths dyed without chalk only eight-tenths of a grain, a quantity sensibly equal to that which is found in the ashes of a white purified stuff.

As the lime found in the goods dyed without chalk might quite as well proceed from a mechanical adherence of this substance to the stuff during the maddering, as from the fact of a combination during the dyeing, they submitted other samples prepared in the same manner to the operations of clearing, that is to say, to treatments with soap, acid, and again with soap; they then burned them, and their ashes gave quantities of lime and alumina, which were found in atomic or proportional relations; that is to say, there were sensibly two equivalents of oxide of alumina and three equivalents of oxide of lime.

Then, after several treatments with acetic acid to take away the chalk, they burned a great number of samples dyed rose-color, ordinary red, and Turkey-red, and the analysis of the ashes proceeding from the incineration of these goods constantly proved the existence of alumina and lime in a simple and invariable relation; so that one might, without too much temerity, lay down this proposition, that the operations of clearing which succeed to those of the maddering, wherewith they are intimately connected, have no other effect than to form a definite quaternary and colored combination, or lake, composed of *lime*, of *alumina* or *iron*, of *coloring matter*, and *fatty bodies*.

It will be objected, perhaps, to these results, that alizarin yields fast colors directly, without the concurrence of chalk, that hence it is necessary to admit either that this tinctorial matter is not the same as the madder, or that, if it be so, the chalk does not play the part which has been attributed to it; but the trials which have been made with alizarin on mordanted goods do not show, in an absolute manner, that it forms on the stuff colored and fast lakes without the intervention of the chalk. The mordanted goods are always, in fact, passed into a dung-bath; now, would not this bath, which naturally contains phosphates and carbonates, and to which, moreover, a certain quantity of chalk is always added, yield to the stuff, notwithstanding the most perfect washings, a sufficient proportion of this substance to form the definite and colored combination which constitutes the lake?

In connection with his previous remarks on pectic acid, Mr. MERCER says:—To increase the dyeing properties of madder, the English dyers use only the astringent vegetals; and these combining with the pectic acid and lime, render these less destructive to the dyeing power of the madder. In Turkey-reds, blood is well known to be almost indispensable; now, the spent madder of Turkey-red dyeing contains little or no coloring matter. Does the blood being always putrid prevent the pectic fermentation, or generation of pectic acid; or, at the time of coagulation, does it cease to hold both the lime and pectic acid? The probability is, that there is no pectic acid formed. As a partial corrective of the injurious effects of this acid in madder dyeing, sumach, valonia, bark, *et cetera*, have long been, and are still greatly used. These astringent vegetals also improve the solubility of most coloring matters in water. They likewise add firmness to the compound or lake of the mordant and feeble coloring matters, such as peachwood, *et cetera*. From the foregoing remarks, it appears to Mr. MERCER that the beneficial use of chalk is mostly due to its power of taking or keeping down the pectic acid.

On the whole, as regards the mode of action of the substances which develop, mask, or destroy the dyeing power of madder, the knowledge acquired is still too limited to admit of giving a full explanation of it. If the oxide of copper and its derivatives destroy the power of this dye-stuff, the reason of it is found in the very combination which is then produced, since the coloring matter and the metal form a whole of a new order; but if some salts increase whilst others diminish the coloring power of this root, these are phenomena which still remain unexplained. If all the salts behaved in the same manner, and all formed an obstacle to the dyeing, one would see in this fact the natural consequence of a very general property in all the coloring matters, namely, that of becoming less soluble in waters charged with saline matters than in pure water; but, as this is not the case, it is better to avow ignorance on this subject than to lose one's self in the region of hypotheses.

Maddering is performed sometimes in one operation, sometimes in two. But the dyer having the greatest interest in getting his dyeings performed at one operation, never divides them into two except in particular cases. It has been stated, that regard should be had to the proportions of water employed for dyeing; in other terms, that a certain relation must exist between the water and the madder: now, as on the one hand the vessels in which the dyeing is performed are of a determinate capacity, and as, on the other, certain kinds of printing require an infinitely stronger proportion of madder than others, it is obvious that it would be difficult to dye in one operation stuffs which require high proportions of madder, for not only, in consequence of not observing the proportion between the water and this substance, one would be liable to lose a very great quantity of coloring matter, but further, this coloring matter not penetrating the stuff with sufficient uniformity, would give only shades more or less unequal.

Other considerations may likewise place the dyer under the necessity of proceeding by a double maddering. It has been remarked, that the colors always lose their vivacity when their mordants are supersaturated with madder; so, to obviate this disadvantage, the dyeing is usually performed in the first place with the quantities either just necessary, or rather too weak than too strong, of this substance; then, the maddering being finished, if the mordants are not saturated, a new dyeing is proceeded with, to give them the quantity of coloring matter in which they are wanting.

For the good execution of several kinds of work, it is indispensable to make sure of the perfect saturation of the mordants dyed in madder, especially for that of the colors which must stand clearings, or which are destined to pass into new dye-baths. If, for example, it is desired to re-enter mordants of iron or alumina on a white maddered ground, to be subsequently dyed in quercitron, then, if the original madder-dyed mordants are not perfectly saturated with coloring matter, the reds and violets, by attracting the yellow matter, pass, the former to orange or to a dull red tint, the latter to olive-grey. It may be known by several signs if a mordant is not saturated; first, by the appearance of the bath, which becomes clear or *poor* when it is exhausted; but this mark is not very precise: next, by the confusion of the different kinds of red, which are well defined only when the mordants are saturated; lastly, by the readiness with which these same colors pass to a yellowish tint on the meadow.

By associating with the madder other coloring matters, compound hues are obtained. There is, for example, a yellow coloring matter which, by acting concurrently with that of the madder, produces on the mordants of alumina, tints which tend more or less to orange-red and even to orange-yellow, according to the proportions; and on the mordants of iron and alumina very different shades, from wood and cinnamon colors to the deepest bronzes, according to the relative quantities of the iron and alumina mordants on the one hand, and the tinctorial matters on the other.

In the dyeing of those colors compounded of madder and other substances, the affinity of which for the mordants is not the same, it is necessary to take care either to employ the exact quantity of madder, if one wishes to mix together all the substances which must go to the formation of a color, or else to dye in two operations, and according to the shade which is wished to be given to the color, or to begin with the madder shade, to be afterwards passed into the bath of yellow coloring matter, or else to pass the stuff into the yellow bath, and from being saturated with this, to dip it then in the madder, with the precaution of stopping when the latter, by displacing a sufficient quantity of yellow coloring matter, shall have created the desired effect.

It results from all which has been said on the subject of maddering, that every printer should attend to the following rules:—

First, Take care to print only goods perfectly bleached and free from fatty bodies; otherwise the impurities of the stuff attract the mordants during the dunging, and at the dyeing fix coloring matter which alters either the printed parts, or those which should remain blank. Second, Observe that the fixing or dunging be as perfect as possible, especially in a madder dyeing—for with quercitron or some other dyes, this is less important—as well as the complementary washing operations. The printer will know that these operations have been well performed when, on rubbing a part of the stuff with the nail, nothing comes off, and on wringing the same part, the water which passes from it is perfectly clear. Third, Pay attention to gradually elevate the dye-baths, and never let them fall to be raised again. Fourth, Proportion the water made use of, to the quantity of madder employed, keeping in view the quality of the madder and nature of the solvent. Fifth, Ascertain the degrees of temperature which best suit the shades he wishes to produce, some of which can only be obtained at low, others at much higher temperatures, and not to forget that, all other circumstances being equal, the maddered shades are duller and the white parts of the stuff more stained in proportion as the dyeing has been performed at a higher heat; that by prolonging the duration of a dyeing, the same effect is produced as by raising the temperature to extract from the madder all its coloring principle; that under 70° there is no dyeing effect, and that the coloring matter produces its best effect between 100° and 140°. Sixth, Use as far as possible pure waters, which, besides the economy in madder which they procure, offer further the immense advantage of charging but slightly the blank parts of the stuff, which, not being covered with mordant, should remain in their natural state; or, if he is under the necessity of employing waters that are impure and loaded with saline matters, he must correct them, not only with the view of obtaining more considerable returns, but likewise that they may injure as little as possible the parts of the stuff which are to remain blank; for what would be the good of shades full and bright after the dyeing, if they should be degraded by the numerous operations and the more or less powerful agents which it would be necessary to employ to bring back the blank parts of the stuff to their original purity? Seventh, Not to forget that every dyeing with madder does not give rise to bright and fast shades, capable of standing the operations of clearing, except in so far as it is performed in presence of a certain quantity of chalk; consequently, that the dyeings which might be done with Alsace madders and pure water could not be submitted to these operations. Eighth, To proportion the quantity of madder to the quality and strength of the mordants deposited on the stuff, knowing that not only is there a loss in employing the madder in excess, but further, that the colors obtained under the influence of this excess are always dull.

5*th*, *Clearing*.—On coming out of the madder-bath, the colors are far from having the lustre, liveliness, and purity of those shades which are so much admired; they must first undergo several operations essential and indispensable to free them from the foreign matters which accompany them, and to acquire, along with these qualities, the fastness or durability of which they possess so little beforehand, that a short exposure to the sun would be sufficient to alter them. This effect, which adds at the same time to their lustre, is due to the soap.

It may here be remarked that the violet mordants, compared with those of alumina, present a peculiarity which must not be passed over in silence: when they are immersed in a dye-bath, they acquire directly the purest shade, so that, if they become dull, it is only by the deposit which is formed on the whole stuff, and which alters the white as well as the dyed parts of it; it may therefore be assumed, that if it were possible to preserve all its purity to the stuff during the dyeing, the finest violet shades would be the immediate consequence of that operation. The red mordants, on the contrary, whatever precautions be taken, and at whatever period in the dyeing they be examined, have always a brick or brownish orange shade more or less decided; they differ, therefore, from the violets in respect that the colors which they produce require to be cleared and fixed, whilst the violets demand only, so to speak, the operations necessary to fix them.

It is not very long since a perfect ignorance existed as to the essential object of the operations which follow the dyeing, and which are about to be passed in review. No other purpose was assigned to them but that of bringing back to their primitive state the blank parts of the stuff stained by the dyeing; it was far from being suspected that it is to these operations that the colors produced by the madder owe their stability, and particularly that the agent—soap—which is specially used to test the fixity of a color, in consequence of the powerful action which it exerts upon it, is precisely the body which gives the greatest stability to the tinctorial matter. It is not surprising, therefore, that not having settled views on this point, printers did not know the most suitable substance to employ, and that they could find no better name to give to those important operations than that of the *bleaching of maddered stuffs.*

At the end of the last century, the goods, on coming out of the maddering, and after being washed, were exposed for weeks on the field to the action of the air and the sun's rays, and watered from time to time. When they began to bleach, and their colors to get weak, they were taken up again to be boiled in a water holding in suspension a certain quantity of dung or of bran. This operation had for its object to accelerate the decoloration of the stuff, and by reducing the number of the days of exposure on the field, to diminish the unfavorable risks inseparable from this kind of bleaching.

Delormois, who visited several dye-works in Holland and Switzerland, and who wrote an excellent little volume, entitled, *The Art of Calico Printing*, Paris, 1786; **Scheffer**, in 1787, and **Berthollet**, in 1804, point out no other processes. So little at that time were the effects which soap produces in such circumstances suspected, that, in the second edition of **Scheffer**, published in 1803, it is said: *Soap-water weakens and destroys the fastest madder color, that even of Turkey-red; whence it follows that soap must be used as sparingly as possible in washing cottons which have this color.*

The unpublished notes of M. **Daniel Kœchlin**, however, which date from 1804, prove that at that time soap was beginning to be employed for this purpose. In his establishment the process followed was this:—The goods, rinsed and perfectly washed on coming out from the maddering, underwent, before being exposed on the meadow, two successive clearings in a bath of soap and bran, which was composed for twelve pieces, representing about two hundred and twenty yards of cloth, by adding to the boiler filled with water—

For the first clearing 4·5 pounds of soap and ·25 bushel of bran.
" second " 2·2 " "

When the baths were in full ebullition, the goods were immersed in them, and circulated by a wince, keeping them at this temperature during thirty to forty minutes. Rinsed and perfectly scoured after each wincing, they were then carried to the field, where they remained exposed from five to eight days, according to the season and state of the atmosphere. They were then taken up to be subjected to a new wincing in a soap-bath at ebullition, and formed this time of two pounds of soap and one gallon of bran. After washing and scouring as before, they were exposed again on the meadow during seven days, subjected to a fourth wincing in soap exactly the same as the last, and then, according to their state, they were put back on the meadow three, four, or six days. The fourth part of the goods, at most, were thus completely bleached; those which remained underwent a fifth wincing, and a new exposure of seven days on the meadow.

Having recited the old methods, the Editor will proceed, in the first place, to give a condensed statement of the operations of clearing, such as they are now performed, and will then endeavor to explain the action of the agents which are used.

The operation of *clearing*—a name which designates the process by which the maddered colors are brightened and fixed—is performed in the same kind of *becks* as those which are used for the maddering, and in a dye-work there are always some of these vessels specially devoted to this operation. To the volume of water necessary to cover the goods, quantities of soap are added proportional to that of the color with which the stuff is covered, but not losing sight of the fact, that colors with a base of alumina require generally a larger portion of this saline compound.

When the goods have been withdrawn from the madder-bath, they are placed, after being perfectly washed and scoured, in a beck filled with a solution of soap, as if it were intended to dye them anew, and are made to circulate, mechanically if common goods, by hand if they are muslins, book muslins, *et cetera.* The operation is usually commenced at the temperature of 65° or 70°, which is progressively raised to the degree of heat which fixes and determines, at the time of this first wincing, the nature of the shade which it is desired to obtain. This is an essential point; if it be neglected, all the precautions which have been taken in the preceding operations to obtain pure and delicate dyes become useless. An example will make this better understood.

If a stuff mordanted for bright rose-color has been maddered, and it has been dyed at a low temperature, by passing it into soap at 100° for one hour, the desired shade will be arrived at by immersions in acid, and soap-baths subsequently given; on the contrary, the printer will never succeed if he has had the imprudence to give the first wincing at the temperature of 170° or 180°, much less if at 212°, unless, as HAUSSMANN advanced, the stuff has been previously treated with pure water heated at high pressure in a close boiler. The reason of this difference is, that the wincing in soap has the effect of fixing the coloring matter, and of rendering it infinitely less easily acted on by the agents, and that this fixation is so much the more energetic as the temperature is more elevated. Nevertheless, this observation applies only to colors with a base of alumina; if, therefore, goods dyed in violet are to be cleared with soap, one may without disadvantage submit them to the action of the soap at a high temperature, since the violet requires, as has been stated, only to be fixed.

As regards the duration of the operation, experience proves that it is useless, if not hurtful, to prolong it beyond one hour.

During the circulation of the goods in the soap-bath, the latter changes its nature, and modifies the colors with which they are covered; the coloring matter which sullies the white of the stuff, is fixed upon it by the lime, as has been proved by direct experiments; there is then formation of insoluble oleate, stearate, and margarate of lime; at the same time the coloring matter enters into solution in the bath, and the white parts of the stuff are purified, unless their coloration be due to portions of oxides which might be diffused in the dung-bath during the operation of dunging, and which, by fixing on the stuff like mordants, might have attracted the dye. On the other hand, the colored parts becoming deprived of the color which is not intimately fixed, and of that which is not to form part of the lake, the soap-bath contracts a pretty deep red hue, and is found in many cases so rich in tinctorial matter that one may dye certain styles by it with advantage.

Besides that the bath gets charged with color, it further undergoes a change which affords a key to the part which the soap performs. In the beginning it is frothy, but by degrees, and in proportion as it is longer in contact with the goods and the temperature rises, it loses this foamy appearance, as if all the fatty substance were taken from it by the stuff, and becomes thin. In this state the gross color has gone down, and that which is in solution is very pure, and now re-dyes and feeds the mordanted part. Whilst a new soap-bath scours and reduces, many inferior lilacs are cured by wincing in this kind of spent soap-bath. If then left to cool, it forms a deposit of fatty acid and coloring matter, united with lime, and the clear liquor from which this deposit is produced no longer contains fatty bodies in solution, since it is not rendered sensibly turbid by the acids.

The proof that this passage in soap has not only the result of bringing back to white the parts soiled by the dyeing, and of depriving the lake of the impurities which accompany it, is, that the colors so treated now resist infinitely better the destructive influence of the light, and of different agents, as chlorine and the acids.

Sometimes, immediately after scouring and cleaning the goods, they are given a second wincing in soap; but one never goes further than this, because experience has shown that it is in vain, even by augmenting the proportion of soap, to try to fix in this manner a greater quantity of fatty bodies; the only result would be a weakening of the colors, and by no means a clearing in any proportion to the agent employed.

After this first action of the soap, it is necessary, in order that the colors may be able to assimilate a greater quantity of fatty substance, and acquire more lustre and fixity, that they should undergo the influence of the air, or of chlorine, or of acids; but all kinds of work do not equally stand the intervention of these different agents: thus, very delicate cylinder printings will scarcely admit of exposure to the air, whilst they agree better with acids or acid salts; on the contrary, stuffs on which there are several reds, especially deep reds, containing a strong proportion of mordant, are treated in preference by the air, seeing that the acids to the action of which they would be submitted, by taking away a portion of the base from the different shades of a pattern, would degrade them to the extent of making those distinctions disappear which one has so much interest in preserving between them.

By exposure to the atmosphere, the goods become of a purer white, but they soon contract an odor of rancidity, more or less analogous to that exhaled by oiled cloths, and the colors which at first become more lively are not long in changing; the reds turn to orange, and the violets to grey. It is for the dyer, who ought to know the maximum effect to realize during the first exposure, to stop in time enough not to compromise his success.

When acids are applied instead of air, the operation is performed in a beck surmounted by a reel, and containing water acidulated either with nitric acid, sulphuric acid, or chloride of tin; the latter—technically termed *stannic soap*—is only used for pink reds, and not for iron mordants. The quantity and proportion of these acids vary with the kinds of printing and the shades desired. Formerly, a mixture of soap and salt of tin was used, but soon perceiving that, at bottom, this preparation acted only by the acid which it contained, printers replaced it, for greater economy, by the nitric acid, and, better still, by sulphuric acid. Nevertheless, the stannic compound gives rise, in certain cases, to secondary effects which must not be overlooked; thus, when the colors are very readily acted on by the acid, there may be deposited in the blank parts of the stuff a portion which becomes fixed and stains them, and in this case the soap, which acts physically, prevents the evil by seizing on the color. On the other hand, the stannic compound often determines a displacement and a true substitution, which has for its result to introduce into the lake a certain quantity of tin which modifies its shade; but again, and lastly, its action, which is always less powerful, permits of brightening, in addition to reds, such colors as blacks and violets, on which the acids exert a too marked influence.

Whatever be the reason, there are cases in which treatments with even very powerful acids are always preferable to those with soap of tin: this happens when the color, after being already fixed and submitted to the solution of tin and bran, is very deep and presents a great resistance.

The goods should be circulated in the acid-bath till the colors undergo the desired modifications—till the reds, for example, turn orange-red, and the roses orange. This modification of the maddered color is produced the more easily, the lower the temperature at which this color has received the first soap, or, in other words, with greater difficulty the more it is saturated with soap, and especially if it has undergone a long exposure to the air. Thus, all other circumstances being equal, two colors of the same shade and tone will be equally modified by an acid of the same kind and strength, only in so far as they shall have fixed the same quantity of soap, and been submitted to the action of the air during the same space of time.

The acid water into which the goods are thus passed contains a pretty strong proportion of coloring matter, which always tinges it an orange-yellow. The proportion of this coloring matter is so much the greater as one makes use of an acid more or less concentrated, and in proportion as the goods passed into acid were covered with deeper shades, that is to say, colors richer in mordant.

After exposing the goods to the air, or passing them into an acid-bath, they are immediately thrown into a new soap-bath, similar to that already described, which has for effect to render the hues more lively and stable.

A second exposure to the air, or a second wincing in acid, and a third in soap, are often indispensable; sometimes one is even obliged to multiply the number of these operations, according to the process which one follows; but this is not the point to be discussed at present: suffice it to say that, at bottom, these operations are always the same, but that sometimes the high temperature of the last soap-baths having no longer the same influence on the shades, it becomes necessary to give these baths in a close boiler at the pressure of four atmospheres.

In these different circumstances, and especially when the last immersion is performed in a close boiler, the coloring matter of the madder undergoes a true modification, somewhat analogous to that which is produced on it by a long exposure to the air in the course of treatments with soap; it is difficult, at least, to admit the contrary in presence of the following facts:—When the printed goods, on coming from the maddering, are passed into an acid-bath, whatever be, so to speak, the degree of dilution of this bath, the colors with which they are covered are immediately modified; the reds pass to orange, and the violets to a dirty olive tint. If at the instant when these colors are so modified, one proceeds to immerse the stuff which is covered with them in a milk of lime, all the tints—red, rose, violet, lilac, and black—pass immediately to the most lively violaceous blue, but more or less intense, and preserve momentarily this shade. Now, if one repeats this operation on the same goods covered with the same colors, especially after they have undergone all the operations of clearing, and the last passage in soap has been given at a high temperature in the close boiler, one finds that the acid which at the beginning exerted so lively an action upon it, no longer produces any effect, and that the lime is no longer capable of turning to blue the portions which the acid has touched. This experiment is so plain, that by observing, watch in hand, the duration of the contact with the acid, one may follow perfectly the progress of the clearing by the greater and greater resistance which the colors oppose to the action of the acids, and consequently of the lime.

From these facts it is natural to ask, whether the coloring matter, brought to this point of fixation, is identical with what it was at the moment when it combined with the mordant? One of two things must hold: either the mordants are modified, and become of such a nature as not to be acted on by the acids, and hence no displacement can take place, or else they experience only an insensible modification, and it is the coloring matter which is metamorphosed. The former of these suppositions is not without some appearance of truth; it results from many scattered facts, that the oxides which here play the part of mordants, and even their basic saline compounds, are modified with the greatest readiness by the action of heat; but the second hypothesis is perhaps better founded. It has been ascertained by direct experiments, that the coloring principle of the madder does not combine purely and simply with the sesquioxide of iron, as one is generally led to assume; but that this oxide, which is formed ultimately on the cloth after the operations of printing and fixing the mordants, by yielding a portion of its oxygen to the coloring matter, oxidizes it, and then passes to an inferior degree of oxidation. If it were not so, one would have difficulty in explaining how lilac, violet, and black could result from the combination of the oxide or rust color, more or less deep, with a matter which, in its present state of isolation, has a weak orange-red tint.

According to this opinion, based on the reduction of the sesquioxide of iron, the red tints obtained from the madder would be formed in other conditions than the violet tints; the coloring matter would not be in the same state. Now, does one not arrive at this result by studying the dyeing of the mordants during the maddering? Do not the violet colors take, of themselves, without the co-operation of intermediaries, the purest tints, while the reds acquire only a brown shade, quite different from that which they contract at last after the wincings in soap, and especially by the exposures to the air, or the treatments with chlorine or with acids? Is it not natural, therefore, to think that these operations have chiefly as their effect to determine the chemical changes which give to the coloring matter properties it does not possess, either in its state of isolation or in its original combination with the mordant? It is to no purpose to allege, that in the maddering the red matter exists ready formed, but that its combinations are soiled by the foreign bodies which accompany it in the madder, and which the clearing must take away from it; for, without absolutely disallowing the partial effect of these foreign bodies in the determination of the fundamental shade, it will be sufficient to recall the fact, that the purest coloring matter, that which is disengaged from the brightened Turkey-reds and violets or rose-colors, furnishes precisely the same tints as the madder, and that it is indispensable to submit these tints to the operations of clearing to give them all their brilliance.

Having now explained the operation of the clearing in its details, and the effects which it produces, a few remarks will be made on the substances required in the operation.

Abstracting the influence which the waters may exercise on this process by the nature of the salts which they contain, one can understand without difficulty how, in an economical point of view, it is important to the dyer or printer to use pure water, since otherwise he is obliged to employ in mere loss a great quantity of soap for the decomposition of the calcareous salts. If, therefore, he is constrained to use water of this nature, he will require to remove its bases by suitable portions of carbonate of soda, or caustic soda, according as they shall be charged or not with bicarbonate, in order to transform the salts of lime and magnesia into insoluble carbonates. The corresponding salts of soda which take their rise from the double decomposition, have no injurious action on waters so purified; nevertheless, the soda should never be employed in excess, and, consequently, if, by any cause whatever, it came to predominate in the liquid, it would be necessary to saturate it with a corresponding quantity of sulphuric acid.

It is a point on which dyers are generally agreed, that one should not use an alkaline soap for the first immersions; on the one hand, the alkaline bases, having a strong tendency to dissolve the alumina—the base of the red mordants—such mordants, saturated with coloring matters, always give way on passing into baths of alkaline soap, and leave there a portion of their oxide. On the other hand, this excess of alkali becomes an obstacle to the realization of the most important effect of the operation, that of fixing the fatty body. The soap, in fact, when it is neutral, undergoes a decomposition under the influence of a great quantity of water; the base and the fatty acids then separate, to pass into two new salts—an alkaline salt which remains in solution, and an acid one which is set at liberty, and gives to the water a milky appearance; in a word, it is the same phenomenon as that which is produced by a liberal addition of distilled water to a transparent solution of soap; the latter gets clouded, and deposits at length two insoluble bi-salts. It is by reason of the formation of these that the colors become saturated with fatty bodies, seizing by their bases—and the lime might here play an important part—the excess of fatty acid to form a neutral soap, which is destroyed in its turn, till the liquor, becoming too alkaline, is no longer decomposable either by water or by the colored lake. To endeavor to prevent the formation of these bi-salts, by employing either an alkaline soap, which is less liable to undergo the kind of decomposition which has just been referred to, or concentrated saponaceous solutions which are not less so, would be to defeat the very end proposed. The necessity of making use of soap free from alkali is so strongly felt, that compounds of this nature are always rejected for clearings, or they are used only by adding, either directly or indirectly, a certain quantity of fatty body; thus, certain dyers supersaturate a solution of soap with oleic acid, for example, which proceeds from the fabrication of wax lights, or, in default of the latter, add sulphuric acid to this solution, heated, till the fatty acids, which precipitate and reenter into solution under the influence of the excess of alkali, cease to redissolve.

The necessity of employing a neutral soap is dispensed with for the last immersions, seeing that for most kinds of work a certain quantity of carbonate of soda is commonly added to the bath.

M. E. SCHWARTZ alleges that all the fatty bodies are not fitted for the making of soaps suitable for the clearing of maddered colors, and especially those that have been treated with chlorine or with nitric acid.

It will be impossible to enter here into any detail on the nature of the acids, or the kind and proportion of that which it is best to employ in particular cases. It may be stated, however, that if all of them lead to the same final result, that is to say, to the purification of the colored lake which exists on the stuff, it is far from being the case that they all brighten the colors to the same degree; in this respect, the phosphoric acid is infinitely less trying to the mordants than the nitric and sulphuric acids.

The following general rules are given by PERSOZ for the guidance of the printer or dyer in the operations of clearing:—

First, That the different kinds of printing require a first wincing in soap at a set temperature for each of them, and that this first operation having for its object to fix the coloring matter, the dyes will take so much the more fixity in proportion as this temperature is higher; and that, if the color is not sufficiently modified at the moment of its being fixed, it will be extremely difficult, if not impossible, to clear it.

Second, That an exposure to the air or a passage in acid must always succeed that in soap, in order that the action of the latter may be efficacious in the subsequent immersions.

Third, That the colors acquire so much the more fixity in proportion as the fatty body accumulates on the stuff in greater quantity, up to certain limits, nevertheless, beyond which the soap is without effect.

Fourth, That the air does not exert the same action as the acids, and that the colors which have been exposed to its influence are always more solid and less jaded than the others.

Fifth, That it is not a matter of indifference to employ an acid of any kind or strength in the clearing; that the nature and proportions of this acid must be regulated according to the work under treatment, and according as the acid immersion succeeds or not to the first, the second, or the third wincing in soap.

Sixth, That the immersions in the close boiler with which the operations of heightening are often concluded, have for their object to determine the strongest degree of fixity of the colored lakes, and thus give, in many respects, the same result as a long exposure to the air, and to the influence of the luminous rays.

Clearing with Bran.—It has been shown that madder dyeings, performed in certain conditions, not only stand the action of soap, but further owe to this body, which possesses in a high degree the power of bringing back to their primitive state the unprinted parts of the stuff stained by the dye, their liveliness and their solidity. There are colors, however, such as those which are obtained from the Alsace madder in presence of pure water, and without the co-operation of chalk, from garancin, weld, quercitron, India wood, Brazil wood, cochineal, and some other dyes, which never experience the action of a soap-bath without their shades being either modified or greatly deteriorated. It is with the view of preventing these degradations of the tints, while clearing the colors and bleaching the ground, that after a dyeing the clearings with soap are in many cases substituted by immersions in bran, which have for their object to remove by boiling—along with the coloring substances with which the unmordanted parts of the stuff get loaded during the dyeing—the brownish matters which tarnish the shades of those parts that are mordanted. These immersions are given in the same manner and in the same apparatus as the soap-baths.

As the consumption of bran is now pretty considerable, especially in the execution of certain kinds of work, M. **Daniel Kœchlin**, with the view of regulating the expense, determined by a series of experiments the following points:—First, The quantity that is required of it for the treatment of a certain number of pieces; second, the temperature and duration of an immersion; third, the most suitable quantity of water for the operation; fourth, the kind and quality of bran to which the preference should be given; and fifth, which part of the bran, the soluble or insoluble part, produces the greatest effect.

All his operations were conducted in ordinary dye-becks, containing two hundred and twenty to two hundred and sixty gallons of water, on ten pieces of calico of common quality, forming a total of about three hundred and twenty yards in length, maddered two and a half hours, and five minutes' boiling.

To resolve the first question, ten pieces were boiled comparatively, and during one hour:—

1st, In pure water.
2nd, In water mixed with 14 pounds of bran.
3rd, " " 28 "
4th, " " 57 "

And it was found that the most suitable proportion of bran was twenty-eight pounds—that a less quantity did not give all the effect desired, that a stronger proportion was pure loss. To know whether, when strengthened with suitable additions of the same substance, an exhausted bran-bath was capable of giving the same results, ten new pieces were passed into each of the above baths, with a small proportion of bran added, and the colors, on coming out of this bath, were found as well cleared as those of the goods which had been passed into it in the first instance; the ground alone was not so pure.

To resolve the second question—the proper temperature and duration of an immersion—he passed the goods into three baths, each containing twenty-eight pounds of bran, brought to ebullition, namely:—

The first for...............	15 minutes.
The second for............	30 "
The third for..............	60 "

Fifteen minutes sufficed to clear the white parts, but thirty minutes were necessary to give to the color all its fixity; beyond this limit there was no appreciable difference between the results obtained at thirty minutes and sixty minutes.

To determine the quantity of water strictly necessary for the operation, two experiments were made:—

The first on... 130 gallons of water and 28 pounds of bran.
The second on 260 " " "

The white ground of the pieces submitted to the action of these baths was found sensibly alike; if a very slight difference existed, it was in favor of the pieces which came out of the bath formed with the greatest body of water; nevertheless, M. **Daniel Kœchlin** pronounces in favor of the small proportion of this liquid, in consideration of the less expense in fuel which it requires.

To know the kind of bran which it is preferable to employ, ten new pieces were passed into three different baths brought up and kept seething during one hour:—

The first formed of 28 pounds of wheat bran.
The second " " rye bran.
The third " " barley bran.

From the result obtained, there was an unquestionable advantage in using wheat bran; the rye bran likewise exerts a sensible action; as for the barley bran, it produces no effect.

To decide whether coarse bran is more advantageous, ten new pieces were passed into three different baths, brought to ebullition and kept at this point during thirty minutes:—

The first formed of 28 pounds coarse bran, well cleaned.
The second " 28 " fine bran, very floury
The third " {28 " dry bran. / 4·4 " flour.}

The result of these three comparative experiments was in favor of the coarse bran; it was this which rendered the white ground purest, and cleaned the colors best.

Bran treated with boiling water separates into two parts, the one soluble in warm water, which includes the mucilage; the other insoluble, or straw properly so called.

An approximative analysis of the former gave, for one pound:—

	Pounds.
Portion soluble in warm water, formed chiefly of gluten, mucilage, and starch, a part of which precipitates on cooling........	0·288
Portion insoluble in water,........	0·576
Water and loss,........	0·156

On trying comparatively the effect of these two distinct portions on the stuff, it was shown that neither the one nor the other, employed separately, acts so efficaciously as when they are united; the starch would appear to have no influence.

In certain localities, the bran is only employed when it has undergone a previous fermentation.

All kinds of dyeing cannot, like the shades obtained with madder, support the action of boiling bran; there are colors which are powerfully affected by this substance when at a high temperature. One should only use a decoction of bran, therefore, after having brought it to the degree of heat at which the immersion may be made without danger, while obtaining as directly as possible the bleaching of the ground; or else, if the bath is kept at a temperature near ebullition, leave the goods only just the time necessary to clear the white. A fact which must not be lost sight of, and on which M. DANIEL KŒCHLIN is careful to insist, is, that the action of the bran is exerted in an inverse ratio to the temperature at which the dyeing has been performed; thus it would be useless to pass goods into bran water at the temperature of 100°, when the dyeing was performed at ebullition. Lastly, the action of the bran appears to increase with the temperature, for, if maddered pieces be submitted to the action of a bran-bath, under the influence of a high pressure, the white comes out from it perfectly pure, and the colors, especially the violets, acquire a much greater liveliness.

There are some who, in place of wincing in soap or in bran alone, to clear their colors, proceed by alternate immersions in these two substances, or employ baths composed of bran and soap together, alleging that the colors thus acquire greater lustre, are less jaded, and that the white is purer. It must not be forgotten that in this operation the fatty body is indispensable to the stability of the maddered colors, and that the bran does not contain enough of fat to give to the lake the degree of solidity which is necessary to it. The necessity of adding to it a certain quantity of soap is so fully recognised, that to give to the maddered reds and roses all the brilliancy of Turkey-reds, the goods are submitted in some establishments to the following treatment:—After dyeing in madder, they are passed into bran to clear the colors; they are then worked at two different operations in *white liquor*—See TURKEY-RED in this article—dried each time at the temperature of 120° to 140°, and lastly cleared with soap and acid. Others arrive at the same result by a method quite opposite; that is to say, they pad the white stuffs in a soap-bath, dry them, and then print the mordants. The dunging is performed as usual; but it is important to clean well, that no portion of fatty matter may adhere to the unprinted parts.

In concluding this part of the subject, the following summary may be given of one of the best processes for clearing madder colors, when no sumach has been employed in the dyeing. The goods, having been previously well washed at the dash-wheel, are treated as follows:—1. Wince for half an hour in boiling bran-water. 2. Wince for half an hour or more in a dilute solution of chloroxide of sodium or calcium. 3. Boil the goods in soap-water, containing half a pound of soap per piece. 4. Wince a second time in the bleaching liquor, weaker than before. 5. Boil a second time in soap-water.

It will be observed that this process includes both soap and bran; but when the goods are dyed with Dutch madder and sumach, soap cannot be well employed in the clearing process; in that case only bran and chloroxide of calcium or sodium are used, the latter being preferred. If dyed with the form of madder called garancin, neither chloroxide of sodium nor of calcium is admissible.

When the goods have been subjected to the several processes of which the details have been given, namely, *printing*, *drying* and *ageing*, *dunging*, *dyeing*, and *clearing*, they are passed through the usual finishing operations as for bleached goods, and are then ready for the market.

Such is the series of operations practised in the madder style of printing, and which have been detailed at considerable length, because they are of greater importance and far more extensively practised than any other style—including, at the same time, a general and connected view of the principles of calico-printing. Some extensive establishments, indeed, confine themselves almost exclusively to the madder style; or rather, it may be said that, at most printing-houses, the other styles are practised as mere varieties, or constitute only an accessory part of the business. In some cases, as in resist and discharge work, they are engrafted upon the madder style, and form a part of it. This style, it must be remembered, includes not only the use of the dye-stuff from which it receives its name, although, by varying the printed mordants, a great variety of tints and shades from the most permanent blacks and the finest purples, to crimson and pale pink, may be produced with madder alone; it includes also the use of weld, quercitron, cochineal, and other soluble coloring matters, which give to this style of printing an almost unlimited applicability. The most expensive description of calico-printing, called chintz-work—a term descriptive of that kind of printing which is employed for window curtains and other furniture, and which differs so much in the richness and variety of the colors—is produced chiefly by the madder style; and this alone may give the reader an idea of the extent of the resources which it commands.

From these remarks it will be seen that the other styles, not including so many interesting processes and abstruse principles, do not require to be treated at the same length. A mere account of their distinguishing features will be sufficient, in a work which has chiefly for its object the elucidation of the chemical principles involved in the subjects discussed.

II. PADDING STYLE, *for Mineral Colors.*—Colors from metallic oxides are very elegantly applied by this style, either to produce simply a colored ground, or a design in a mineral tinctorial matter on a white or colored ground. When the object is to form a ground for the reception of a design in other colors, the entire surface of the cloth may be impregnated successively, by the padding machine, with the two solutions necessary to produce the color, or else the cloth may be padded in one of the solutions, and afterwards winced in the other. To produce a design, the cloth may be first padded with one of the mordants and then printed with the other, but it is usually first printed with one of the solutions, and then may be either padded or winced in the other.

The method of wincing has been described in treating of the madder style. The padding is performed in a tub or trough containing the mordant, through which the cloth is passed, and then the superfluous mordant is expressed between the rollers. The annexed engraving—Fig. 397—will convey a correct idea of the common *padding machine.* E, F, are two cylinders covered with blanket stuff, and fitting with their journals, *a*, *b*, in slots in an upright, fixed on the frame, A B D C. The cylinder, F, acts as a squeezing roller, and to the pressure which it exerts by its own weight is added that of a lever, *e f*, carrying the weight, *g*. The calico is first rolled around the cylinder, N, furnished with a counterweight, *o*, to stretch the cloth, and from this it passes over a widening roller, *m*, dips into the trough, G, under the roller, C, and afterwards rises over a bar, I, with diverging grooves, to proceed between the two cylinders, E, F, by which the excess of liquid is expressed. It is then wound on the roller, H, the journals of which, *h*, turn in slots in the moveable bars, *i*, *k*, which are guided by a groove in the quadrant, *l*. The lower roller, E, being put in connection with the mover, communicates its motion to the squeezing cylinder, F, which in its turn transmits it to the roller, H. The goods are unrolled from N by the traction exerted by the cylinders, E, F.

Fig. 397.

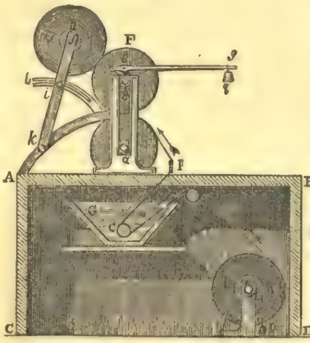
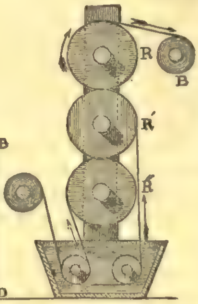


Fig. 398.

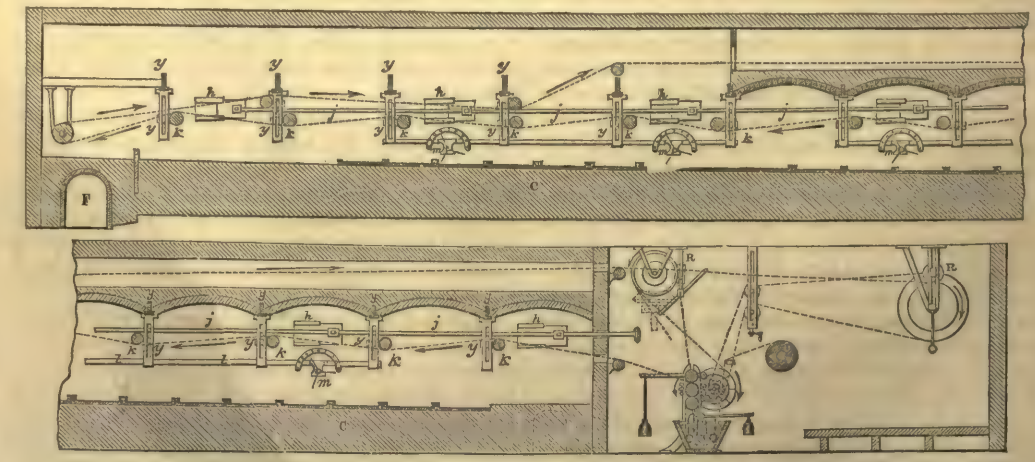


By this machine the cloth can only be passed once through the mordant, except by making the goods rollers change places, and repeating the process. By applying a third roller, however, the immersions and expressions may be given at one operation. This arrangement is represented in Fig. 398. Three cylinders, R, R′, R″, are placed one over another, and kept exactly parallel between the cheeks of a frame similar to that of a printing machine; pressure may also be applied to them by suitable levers. The calico, unrolling itself from A, dips into the mordant trough under the first roller, *n*, rises and passes between the cylinders, R″, R′, dips again into the mordant, and passing round the roller, *m*, is subjected to a second squeezing between the cylinders, R′, R, from which it proceeds to be taken up by B.

If the mordant or color is to be applied to the face of the cloth only, and not to both face and back, the cloth may be passed directly between two cylinders, the lower of which, and not the cloth, is made to dip into the trough; or the common printing machine with a roughened roller, and having the color doctor adjusted so as to allow a certain amount of color to pass, is sometimes substituted in this case for the padding machine. Whatever system be adopted, a perfect parallelism ought to be given to the rollers, to produce an equal pressure, and the speed must be so adjusted that the goods may have sufficient time to be properly impregnated with the liquid.

When padded, the goods are often left a few hours on the roller, to give time to the mordant to penetrate the pores uniformly. They are then dried quite hard by exposure to a temperature of 210° or 212°. This desiccation, indeed, constitutes a part of the padding process, which is not complete without it, and the thorough manner in which it is executed, is of the greatest importance. If not done quickly the whole operation will be a failure, whatever care may be taken in applying the color or mordant to the stuff, since the solutions employed for that purpose, being generally little thickened with gum, or not inspissated at all, will, if not speedily arrested, run or flow upon the goods, and accumulate unequally at different parts of the surface. A fold or crease in the goods, one part dried before another, a too rapid oxidation in some points—all produce centres of attraction which, instead of a plain uniform ground, yield one full of spots and inequalities of shade. To prevent this, the goods are exposed in a state of constant motion to a pretty high temperature, and every precaution is used to keep them properly extended, and to render the action as quick and uniform as possible.

Fig. 399.



For this purpose the goods may be circulated round a series of hollow cylinders heated with steam, as represented at page 317, in connection with the drying of starched goods. Indeed, the starching is simply a padding process; and the mechanism there described may be employed both for padding and drying. Or the goods may be dried in the hot-flue described at page 699. But another and better form of the flue, erected in some of the most extensive establishments, is represented in vertical section in the annexed engraving—Fig. 399.

The principle of this method is to circulate the goods over hollow rollers placed above heated iron plates. The apparatus consists essentially of a large vaulted flue, thirty yards in length, four in width, and three in height, cut in two, for nearly half its length, by six small vaults constructed in an opposite direction to that of the large flue. The object of these small vaults is to protect the large one from the too powerful action of the hot plates, and to prevent the dried goods, on arriving at the upper part, from coming into contact with the acids and moisture which are disengaged in great abundance, and might condense upon them.

C, C, is a long furnace, forming the bottom of the flue; the upper part is covered with iron plates, fitting one upon another, and capable of being brought to a red heat by the action of the flame which circulates under them. The thickness of these plates is not the same over their whole length; it goes on increasing from the point, C, to where they approach nearest the central source of the heat.

F is an arched passage, which gives access to the interior of this stove chamber.

h, *h*, are air-holes in the sides, opening and shutting at pleasure by means of the rod, *j*, fitted with as many valves as there are openings in the wall.

k, *k*, iron supports for rollers of tinned copper, which are fixed to the cross-pieces, *y*, *y*, and serve to conduct the cloth along.

l, *l*, iron bars for sustaining the ventilators, *m*, *m*, which are formed with wings of wire-work or metallic gauze, and make about three hundred revolutions per minute. Instead of placing these ventilators all at the same height, M. EDOUARD SCHWARTZ recommends to arrange them two above and two under the goods.

In front of the flue is exhibited all the mechanism required for the padding of the goods, and for communicating motion to them. This motion is conveyed by pulleys, R, R, which receive their impulse from a prime mover.

No one can doubt the superior advantage of this method of drying the goods, for, in their passage between the hot plates and the vault which radiates the heat, they are dried quickly, and all the better for the ventilators, which, by expelling the acetic acid and water, prevent their condensation. It is, therefore, generally adopted in England in large establishments, but is liable to the objection of being expensive in the construction. Of late, it has been slightly improved by substituting for the conducting rollers two endless bands, furnished with hooks, which travel by means of rollers or pulleys, and are kept extended by springs which stretch the piece in the direction of its breadth.

Processes.—Having described the apparatus for padding and drying, one or two processes may be given to illustrate this style of work.

To produce, for example, a *ground of prussian blue*, the goods may be first padded in a solution of acetate and sulphate of iron, made by adding three pounds of acetate of lead to a solution of four pounds of copperas in a gallon of water, then decanting the iron liquor from the precipitated sulphate of lead, and diluting to the density of 2° or 3° Twaddell. When the cloth has been padded in this solution, it is dried, and then winced in warm chalk-water; after which it is winced in a solution of a pound of yellow prussiate of potassa in forty gallons of warm water, to which are added four ounces of sulphuric acid. This gives a uniform ground of prussian blue.

To produce a *design or pattern* in the same color, the cloth is printed with the mixed solution of acetate and sulphate of iron, made as above, and marking 4° or 5° Twaddell, thickened with gum, and sightened with a little prussiate of potassa. After being aged, the cloth is winced in chalk-water, cleaned, and winced in a solution containing three or four ounces of prussiate of potassa and one fluid ounce of hydrochloric acid per piece, until it acquires the desired shade.

For a *ground of chrome-yellow*, pad in a solution of bichromate of potassa, containing eight ounces of the salt to the gallon of water; then dry with moderate heat, and pad in a solution of acetate or nitrate of lead, containing six or eight ounces in the gallon of water; wash and dry.

To obtain a *light lemon* tint, pad in a solution of acetate of lead of double the above strength, or sixteen ounces to the gallon, then wince the pieces through weak milk of lime; rinse; pad through bichromate of potassa; rinse and dry.

To obtain a *design in chrome-yellow*, the cloth may be printed in a solution containing from seven to ten ounces of acetate of lead, with the same quantity of nitrate of lead, to the gallon, and thickened with starch. After being printed and dried, the cloth is winced first in a weak solution of carbonate of soda, and afterwards in a solution of bichromate of potassa, containing about two ounces per piece. To clear the whites, the cloth may be winced in water slightly acidulated with hydrochloric acid.

Chrome-green is given by padding in a mixed solution of sulphate and acetate of copper, with a little glue, drying in the hot-flue, and next day padding in a caustic lie of specific gravity 1·05. The goods are then rinsed, and padded through a solution made with eight ounces of arsenious acid combined with four ounces of potassa, diluted with two gallons of water; then rinsed and dried as usual.

Iron buff or chamois, manganese bronze, chrome-orange, and other mineral colors, are applied in the same manner, either for grounds or designs. But the processes already given are sufficient to illustrate the principles of this style of calico-printing.

III. TOPICAL STYLE, *for Spirit and Steam Colors.*—Some vegetal dye-stuffs, such as indigo, annotta, and safflower, are either of themselves insoluble, or but slightly soluble in water, and therefore cannot be applied by the common maddering process. When these or their alkaline solutions are formed into a paste and printed on the stuff, some of them acquire a certain fixity by mere exposure to the air, others require that the stuff shall be previously imbued with a mordant, and others can only be fixed by subjecting them to the action of steam. In all these cases, however, the colors themselves, and not the mordants alone, are printed, or topically applied on the cloth, and hence the method of printing such colors is termed the *topical style*.

Spirit Colors.—All fugitive topical colors not fixed by steaming, are termed spirit or fancy colors. Properly speaking, however, the name is applied only to those colors produced by a mixture of vegetal dye-extracts, and solutions of tin, commonly called *spirits* by dyers. These all owe their vivacity, as well as the moderate degree of permanency they possess, to their tin mordant. After printing-on the topical color, the goods are dried at a gentle heat, and then merely require to be passed through the rinsing machine. This process is, therefore, much simpler than either of the two preceding styles. At the same time, the shades communicated in this manner have generally little permanence.

As a specimen of this mode of printing, the following recipe may be given for a *spirit purple*. A gallon of logwood liquor, of 6° Twaddell, is boiled for a few minutes with a pound of starch, and when the mixture is lukewarm a pint and quarter of solution of perchloride—nitro-muriate—of tin at 120° Twaddell is added, and then a quarter of a pint of oil. This mixture must be carefully stirred before applying it to the cloth, which, after being printed with it, is suspended for forty-eight hours in a warm room, and then merely washed at the rinsing machine.

A *spirit chocolate* is given by extract of Brazil-wood, extract of logwood, chloride of tin, and a little nitrate of copper—all mixed, thickened, and merely printed on. The thickening in this case may be either starch or British gum. But a faster chocolate is obtained by first printing on a mixture of logwood liquor, red liquor, and oxalic acid, and after ageing passing the cloth through a solution of bichromate of potassa—a process, however, which cannot properly be called topical printing.

A *spirit red* is obtained by extract of peachwood and tin, with a little nitrate of copper. For a good spirit pink, one gallon of peachwood liquor at 8° Twaddell, is boiled briskly with one and a quarter pound of starch; half a gill of solution of nitrate of copper at 100° Twaddell is then added, and when the mixture is cooled to about blood heat, three gills of solution of perchloride of tin, four ounces of *pink salt*—chloride of tin and ammonium—and one gill of oil are introduced.

Prussian-blue is prepared for topical printing by grinding it in a hand-mill, like that for grinding pepper or coffee, and triturating the powder with solution of chloride of tin; it is then thickened and printed on the stuff. To convert the prussian-blue into green, the goods, after rinsing, are passed through a solution of bichromate of potassa. Indigo communicates a faster blue, so far as the action of soap and alkalies are concerned, than prussian-blue; but the latter possesses considerably more brilliancy than the former in its ordinary state. As a topical color, indigo is applied in the form of indigotin, or the hydride of indigo-blue; the deoxidizing agent employed to produce the indigotin being either metallic tin, or the red sulphide of arsenic—red orpiment or red arsenic. *Pencil-blue* is prepared by mixing with water and boiling together about equal parts of ground indigo, orpiment, and quicklime, and when the mixture is withdrawn from the fire, and has become lukewarm, adding about the same quantity of carbonate of soda as of the other ingredients. The clear liquor, thickened with gum, was formerly applied or grounded-in with the pencil, and hence the name of the color. Till of late years, this was almost the only solution of indigo employed as a topical color; but a preparation, in which the deoxidizing agent is metallic tin, is now commonly substituted for pencil-blue, and is made as follows:—Four pounds of ground indigo are first intimately mixed with four quarts of water, to which are added two and a half quarts of solution of caustic soda of 70° Twaddell, with three pounds of granulated tin. This mixture is heated to the boiling point, then taken off and stirred until a drop placed on a glass plate appears of an orange-yellow color. To this liquor is afterwards added a mixture of a solution of chloride of tin at 120° Twaddell, with an equal measure of hydrochloric acid, until the free alkali is completely neutralized, and an olive-colored precipitate falls. The whole is then well stirred, and added to strong gum-water to the required shade.

Steam Colors.—This name is applied to topical colors printed in the ordinary manner, but fixed by steam. The application of steam to this purpose is quite a modern invention, and is one of the most important improvements in calico-printing. Very few colors attach themselves firmly to the cloth by being merely printed on together with the mordant; but by exposing the cloth so printed—with colors and mordants suitable for the purpose—to the action of steam, the coloring matter becomes attached to the tissues almost as strongly as in any other style of printing; combining, indeed, a degree of brilliancy with solidity of color, which can hardly be obtained in any other way, except by the madder process.

The first attempts which were made to render colors adherent by the application of steam, date from the end of the last century, and BANCROFT, in his work on Permanent Colors, published in 1797, states that he had succeeded in fixing the coloring matter of quercitron by this process. For many years, however, little attention was paid to the subject either in England or on the Continent; but in 1819 this new method of fixing colors was pretty extensively applied in France to woollen and silk goods. From that time it has extended, and is now universally practised by calico-printers on cotton and other fabrics with the best results.

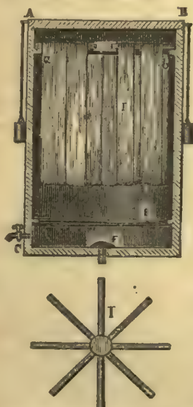
A considerable variety of coloring substances admit of being fixed by this process; and some are directly applied to the goods without subjecting the latter to any preparation except bleaching; but the brilliancy and permanency of almost all steam colors are greatly increased by impregnating the cloth with a solution of tin, or for some styles with a solution of acetate of alumina, previous to the application of the colors. The salts of iron can only be applied in this preliminary process for a colored ground, as this kind of mordanting indelibly stains the fabric, and is therefore incompatible with printing upon a white ground. The solution of tin now commonly used is the stannate of potassa; and after being padded in the solution, the calico is usually passed through a cistern containing a solution of chloride of ammonium, to produce a precipitate of binoxide of tin. When acetate of alumina, or red liquor, is used, the goods are padded with it in the same manner, proportioning the strength of the liquor to the intensity of the shade which it is desired to obtain.

The goods should not be prepared in this manner too long in advance, especially with the tin mordant, which soon loses its property of fixing the colors. When so prepared for those colors which require it, the cloth is printed either by the cylinder or the block, with the mixed coloring materials and mordants properly thickened, or in some cases without the addition of any mordant but that which the stuff has already received. The calico, so printed, is dried in a warm moist atmosphere for a period of forty-eight hours, more or less. It is then ready to be exposed to the action of the steam.

Steaming apparatus.—There are five different forms of apparatus for steaming goods—the cask, the steam-chest, the lantern, the chamber, and the column.

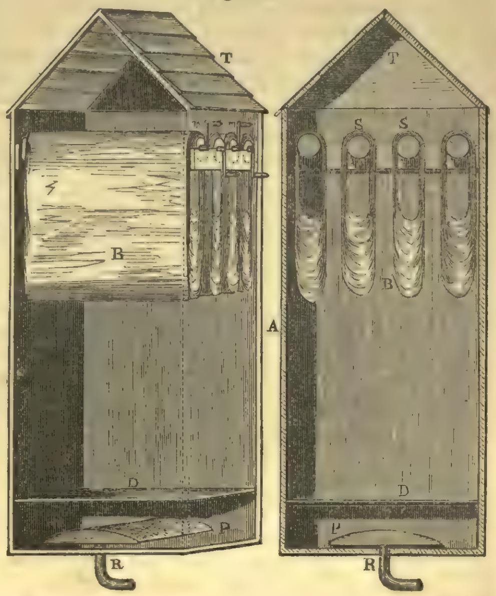
The simplest and oldest method of steaming is by the *cask* or *drum*, which is shown in vertical section in Fig. 400. It consists of a drum of white wood, B A C, the bottom of which is pierced with a hole to admit the steam-pipe, F, terminating in a rose. At three or four inches from the bottom is a canvas partition or diaphragm, E, intended to arrest any drops of water projected from F, and also to separate the condensed water from the goods. Near the upper part of the drum a hoop, *a b*, is fixed, which serves to support the frame, I, on which the goods are suspended to be exposed to the steam; and, lastly, a wooden head, or lid, is fixed on the drum, either by bolts, or by hooks of the form shown in the figure, to which weighted cords are suspended. Sometimes, however, instead of this wooden head, the utility of which is doubtful, the drum is closed with a cloth cover, which permits the air to escape at the commencement of the operation. The frame is studded with pin points, like that of the indigo vat; the goods are hung upon it in the ordinary way, and then wrapped round with flannel. The upper part of the frame must also be covered with flannel, to prevent the deposition of moisture upon it. At the bottom of the drum there is a stop-cock, C, to let off the condensed water. From twenty to thirty minutes is the average time allowed for one steaming operation.

Fig. 400.



The *steam chest* or *box* is another arrangement on the same principle, but more convenient for a large quantity of goods. It is shown in front and side view in Fig. 401. A is the chest, surmounted with its movable head, T; S, S, bobbins on which the goods are suspended, so as to form a kind of endless web, and which can be turned from without by the handles, M, M; D, the canvas diaphragm, or false bottom; R, steam-pipe fitted with a rose, P.

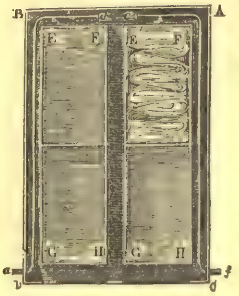
Fig. 401.



The *lantern* may be described by reference to the same figure. It consists of two parts—a movable box, which is properly termed the lantern, and a frame for suspending the goods. The movable box is similar in form to that represented in the last figure, having the same sloping roof to facilitate the trickling down of the water; but is constructed of copper, and is open below, so as to admit of being lowered from the roof by pulleys over the frame. The latter consists of spars of wood mortised together, and is formed like the skeleton of a four-legged table, strengthened with cross bars. Hooks are fixed on two of the opposite sides of this frame, and to these hooks the goods are suspended, so as to cross and recross the frame in zig-zag order. The latter, when filled with goods, and covered with flannels all round, is placed on a fixed table, through the middle of which an aperture is made to admit the steam-pipe; and immediately over the orifice of the pipe is placed a copper disc to spread the steam. When all is ready, the lantern is let down from above over the frame, and its lower part fits exactly into grooves made in the table, which can be stuffed steam-tight with lists of cloth. The steam is then let on, and when all the air has escaped through a small orifice formed in the lantern for that purpose, and nothing but steam is discharged, the orifice is stopped with a cork. The steaming is then continued from thirty to forty or forty-five minutes, according to circumstances; after which the penthouse is drawn up, and the goods are removed and spread out for airing. The height of the sides of the lantern, not including the sloping roof, is four or five feet, and the interior dimensions are six feet by four.

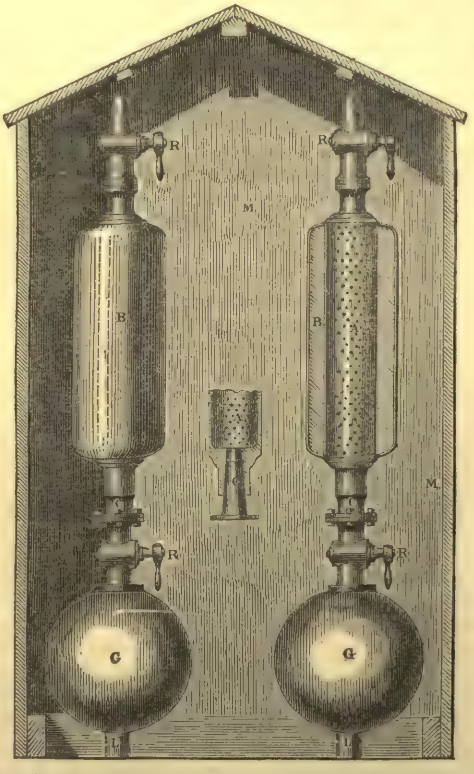
The *chamber*, which is represented in Fig. 402, is an apartment nine feet high, twelve in length, and nine in breadth, fitted with two doors in front, which are made of strong planks, shut by sliding in slots, and secured by strong iron bars and pressure screws. The steam is introduced into this chamber by two pipes, *a b c*, *d e f*, which are shut at the ends *c* and *d*, but are perforated along their sides with small holes to diffuse the steam through the chamber. The goods are suspended on two frames, E F H G, E′ F′ H′ G′, which are movable, and run upon rollers, so as to admit of being drawn out through the doors. The sides of the frame are provided with hooks for hanging the pieces in the zig-zag manner represented in the figure, so that in a chamber of the dimensions above stated, with frames to correspond, from six to seven hundred yards of cloth may be steamed at one operation. There is a safety-valve in the upper part of the chamber to prevent accidents.

Fig. 402.



The preceding forms of apparatus are chiefly used for steaming silks and woollens. For steaming calicoes the *column* is generally used. Two of these columns, the one in elevation, the other in partial section, to show the internal construction, are represented by Fig. 403, enclosed in a kind of lantern or penthouse. They are hollow cylinders of copper, A, from three to five inches in diameter, and about forty-four inches long, perforated over the surface with small holes, and terminating at their lower ends in a pipe, C. This pipe is made with a conical orifice, in which the tube from the boiler exactly fits. The latter is mounted with a stop-cock, R, to regulate the admission of steam; and, as it often happened that, at the moment of opening the stop-cock, water was forced into the cylinder with the steam, the improvement has been introduced of carrying the steam-pipe, L, into boxes or hollow spheres of copper, G, which receive the condensed water before it reaches the stop-cock.

Fig. 403.



In proceeding to steam the printed goods with this apparatus, the cylinder, A, is first lapped round with a few coils of blanket, then with several coils of white calico, next with the printed goods stitched end to end, and, lastly, with an outward covering of white calico, B. To perform this operation more easily, the cylinder is placed in a horizontal frame, in which it is made to revolve in winding the different stuffs upon it. The external envelope, B, is firmly secured with a cord at both ends, and the cylinder with its terminal tube, C, is then fixed upright upon the steam-pipe. The stop-cock, R, is now opened, then the lower stop-cock, and when the air has been driven out from the cylinder, and nothing but steam passes, the upper stop-cock is shut. The steam, having then no other means of escape, passes through the holes in the cylinder, and forces its way through the goods. If the latter were placed in immediate contact with the cylinder, the inner folds would be found to contract a different shade from the rest, and if the external covering were omitted, the outer folds would be very imperfectly steamed, besides being exposed to the danger of the steam condensing upon them. As a further security against this, the use of a lantern or penthouse, M, has been introduced, by which the column is protected from currents of air, and within which a number of such columns may be erected and put in operation at the same time. When the steam is shut off, the goods are immediately uncoiled, to prevent the risk of condensation, which is apt to make the colors run. If the operation has been properly performed, the unrolled pieces are found to be almost free from damp, and require only an exposure of a few minutes in the air to appear perfectly dry.

The action of the steam, applied by any of these methods, in fixing the printed colors on the stuff, is a question involving much interest. Does it produce its effect simply as a calorific agent, or in some other capacity? To determine this point, EDOUARD SCHWARTZ divided into two portions a piece of woollen stuff printed with different colors; and over one of these pieces, while the colors were still moist, he passed immediately an ironing block heated to 212°. In these circumstances he found that the colors were perfectly fixed by the combined action of the moisture of the color and the heat derived from the iron. The other piece was subjected to the same treatment after the colors had been thoroughly desiccated, and it was found that in this case they were not rendered adherent, but could be detached from the stuff by the slightest washing.

PERSOZ justly remarks that this necessity for the presence of a certain quantity of water, to render the steaming effective, is very easily accounted for, since in this operation chemical reactions take place, for which the intervention of water is as indispensable as in the decomposition of sulphate of lead by sulphide of hydrogen. It is known that this gas, which attacks and sulphurizes the sulphate of lead with so much energy in presence of moisture, has, on the contrary, no action upon it in the dry state. Many other examples might be cited of double decompositions between the salts, which can only take place in the same conditions; but at present it may be sufficient to mention two phenomena which happen to be intimately connected with the steaming of colors. The chloride of sodium and silicic acid, brought into contact in the dry state, do not react upon each other; whereas, when water is present, silicate of soda is formed with disengagement of hydrochloric acid. The same chloride in a dry state, and concentrated sulphuric acid, react on each other very slightly; but in presence of a certain quantity of water they may be perfectly decomposed, even at a much lower temperature. Now, it will be found that steam colors are composed of bodies of this description, the reactions of which depend on the presence or absence of water.

The necessity of moisture to that effect which is produced by the steaming of colors, may be familiarly illustrated by the fact, that *dry chlorine gas has no bleaching effect upon goods*, and that it requires the presence of a certain quantity of water or moisture, with the hydrogen of which it combines, while the oxygen is set free to act upon the coloring matters.

But if water is essential, what is the best kind of steam to apply in this operation? Should it be a dry vapor, or steam charged with a considerable amount of water in the globular state, as happens when the supply is feeble or external condensation occurs? It is evident that, if both the colors and the steam are very dry, there will not be sufficient moisture present to produce the necessary reactions; whereas, if too much humidity is present, the colors will run, the pattern will be disfigured, and the shades confused, or the white parts of the stuff will be stained. These considerations involve others—how long the steaming should be kept up—the hygrometrical or drying nature of the colors—the exposure of the goods, after being printed, in a dry or moist place—how long the goods should be so exposed before steaming; and, lastly, the best kind of steaming apparatus to employ in particular cases? To assist the printer in determining these points for himself, according to circumstances, all that can be here attempted is to offer a few general considerations.

With regard to the influence of dry or moist steam, and the time of prolonging the operation, the printer must consider the state of the printed goods, with regard to their humidity, and whether or not they contain bodies capable of fixing a certain quantity of water. To produce clean and well-defined figures, it is advantageous to print with drying colors, but such colors steamed dry under considerable pressure will not be properly fixed, except by exposing them to a prolonged action; and this action, if too long continued, will cause the colors to run. Hence the difficulty of properly adjusting the quality of the steam and all the other circumstances, when, as generally happens, the goods are printed with various colors possessing different hygroscopic qualities. When the goods, after being printed, have been left exposed for some time in a moist atmosphere, dry steam is the best; but if wet steam is applied, the operation must be abridged to prevent the running of the colors, and the further precaution must be taken so to adjust the goods and the whole apparatus, that the steam may diffuse itself rapidly and uniformly in all cases. For this purpose the supply of steam cannot be too abundant; because, by reducing in this manner the duration of the operation, the shades are obtained more uniform. On the contrary, if the steam penetrates slowly into the goods, it does not diffuse itself equally; the parts which it first reaches are saturated with moisture, when other parts are scarcely touched at all; and it will be in vain to attempt to remedy this by prolonging the operation, for long before the last parts arrive at the point of saturation, the others, continuing to condense moisture, will be supersaturated with it, and the colors will run.

There are some printers who steam their goods almost immediately after they are printed. This method may succeed in certain cases, and with some colors; but as a general rule it is not to be recommended, since it is difficult, if not impossible, to give by steaming the same degree of fixity to different colors which have not been all printed on the stuff at the same time, and have not therefore the same degree of humidity. It is better, after bringing all the shades to the same state of desiccation, to expose them to conditions in which they will all absorb the necessary quantity of moisture, and thus acquire a perfect uniformity in that respect.

Again, from the important influence which the state of the goods, as regards their dryness or moisture, exerts in the steaming, it is obvious that care must be taken to place or suspend them on the frames, or to roll them on the cylinder, in an atmosphere as similar in temperature and other conditions as possible to that in which they are submitted to the action of the steam. If taken too cold into the steaming-chamber, moisture will condense upon them as soon as the steam is admitted. All variations in the temperature of the atmosphere to which the goods are exposed, should, therefore, be avoided as much as possible.

With regard to the best kind of steaming apparatus to employ, it is difficult to lay down any general rule. It may be stated, however, that in those which are of large dimensions, there is necessarily a greater condensation of water at the beginning of the operation, and, consequently, colors which have not much of a hygroscopic nature, are placed in good conditions for fixing; but to prevent those which are very hygrometric from running, too much care cannot be taken to diffuse the steam rapidly and equally, and with this view to introduce it in sufficient quantity. The smaller forms of the apparatus do not present the same disadvantage; nevertheless, from the rapidity with which the temperature rises in these circumstances, soon rendering impossible any condensation of the steam, the latter must be applied in a moist state. For this purpose, in steaming with the chest, a certain quantity of water is sometimes put into the bottom of the vessel, through which the steam must pass before arriving at the goods.

In January, 1855, a patent was taken by Mr. JOHN GRAHAM, of Hartshead print-works, near Stalybridge, Lancashire, for improvements in fixing certain colors on yarns and textile fabrics, which consist in subjecting them, after being dyed and printed in the usual manner, to the action of high-pressure steam, or a mixture of high-pressure steam and air, or of water heated and under pressure, or mixed with certain chemical solutions which elevate the boiling point of the liquid, so as to expose the yarns or fabrics, for a shorter period than is usually required in steaming, to a temperature ranging from 250° to 300° Fahr., more or less. The colors or lakes to which these improvements are described as having been found most applicable, are garancin, madder, cochineal, logwood, sumach, quercitron, and other dye-stuffs of the same nature, in combination with the oxide of iron, alumina, tin, and other mordants. The special methods enumerated in the specification of this patent are as follow:—1st, The goods may be put into a strong close vessel, in which they are subjected for a period of twenty minutes, more or less, to the action of steam at a pressure of forty pounds on the square inch; or 2nd, Into a vessel containing water, which is then closed, and heated to a temperature of from 250° to 300°, for twenty minutes; or 3rd, Into a vessel which may be open, and in which the goods are submitted, for the same period, to the action of steam alone, or of steam mixed with air at 250° to 300°; or 4th, They may be passed through a strong or nearly saturated solution, capable of being heated to a temperature varying from 220° to 260° Fahr., such as sulphate of soda, chloride of sodium, arseniate of soda, chloride of calcium, or other salts of a similar nature. By thus elevating the temperature either of the vapor or liquid to which the goods are submitted, the duration of the process is abridged, and the fixation of the colors is alleged to be more effectually accomplished.

A few examples may now be given of colors that are printed to be fixed by the steaming process.

Steam-red.—For steam-reds, the coloring matter of cochineal and the decoctions of certain dye-woods, particularly Brazil-wood, are used. In the execution of steam work, the cloth is first run through stannate of soda, then through dilute sulphuric acid. The stannic acid is thus fixed, though it is not a strong base, but when the coloring matter contains alum mordant, the tin gives to all the colors, by its insolubility and its acid character, a richness which cannot be obtained with any other known substance. For Brazil-wood the goods are prepared with a mordant of nitro-acetate of alumina, more or less concentrated; and, as liquors of Brazil, Sapan, and other woods, are usually in a low state of oxidation when they come from the chemical manufacturer, a little chlorate of potassa is added, which supplies the requisite element, and leads to the development of finer and fuller colors than would otherwise be obtained; but the best steam-red for cotton is obtained by decoction of cochineal with oxalic acid and protochloride of tin. For this purpose, one gallon of cochineal liquor of 6° Twaddell is boiled with one pound of starch for a few minutes; when this mixture is half cold, three ounces of oxalic acid are added, and as soon as the acid is dissolved, four ounces of crystallized protochloride of tin are introduced. By substituting peachwood for the cochineal liquor, a cheaper, but less brilliant steam-red is obtained.

Steam-yellow.—For steam-yellows, quercitron or fustic, with an aluminous mordant, may be used; but as the coloring principle of Persian berries is much more soluble than that of quercitron, and yields purer shades, it is usually preferred for this purpose. Steam-yellows may be printed on the cloth without subjecting it to any preliminary process; but the shades are brighter and firmer when the goods have been prepared with tin mordants. For a quercitron yellow, to one gallon of the decoction at 7° Twaddell, add one pound of alum dissolved in a quart of water, and thicken with three and a half pounds of gum Senegal. For yellow from decoction of Persian berries, to one gallon of berry liquor at 4° Twaddell, add five ounces of alum thickened with about fourteen ounces of starch. Or, in one gallon of berry liquor at 8° Twaddell, dissolve twenty ounces of alum, and thicken with three ounces of gum Senegal, adding a small proportion of chloride of tin.

Steam-violet.—Steam violets, like the reds and roses, have for their base an aluminous mordant, and the coloring matter is decoction of campeachy, either by itself or mixed with Brazil-wood to modify the bluish tint.

Steam-blue.—The only blues which have yet been fixed by steam are the prussian, either pure or mixed with oxide or cyanide of tin. Indigotin has not yet been applied in this way, its fixation being impossible except by reducing it in presence of a salifiable base, which, by rendering it soluble, enables it to combine with the stuff. For a good steam-blue, dissolve in one gallon of water 6·4 pounds of ferrocyanide of potassium; in another gallon of water dissolve 3·35 pounds of alum, two and a half pounds of oxalic acid, and two and a half pounds of tartaric acid. Mix these liquors, which may be colored with a little nitrate of iron, and thicken with gum. For woollens, bichloride of tin is preferred to the alum; but the latter is used for cotton goods.

For printing on cottons by the cylinder, a very good prussian-blue is obtained by mixing with one gallon of water, one pound and a quarter of yellow prussiate, three to four ounces of alum, five to six ounces of sulphuric acid, thickening with one and a half pounds of starch.

Steam-greens have for their base the ingredients employed for steam-blue, associated with those already given for steam-yellow, varying the proportions according to the shade desired. Though indigo has not yet been applied by the steaming process either for blues or greens, PERSOZ thinks it might be rendered available for that purpose by mixing with it a reducing body, and printing and steaming in presence of ammoniacal gas. Rendered momentarily soluble, it might in these conditions penetrate into the pores of the stuff, to which it would adhere on being oxidized either by exposure to the air or by employing an oxidizing agent.

All the *steam-blacks* are formed by a combination of logwood liquor with nut-gall and iron mordants; but some contain only these principles, while a small proportion of fatty matter, such as Gallipoli oil, is introduced into others.

IV. RESIST STYLE.—The principle of the *resist* or *reserve* style consists in the topical application of some substance which has the effect of protecting those parts of the fabric on which it is applied, from the action of the mordants or tinctorial matters in which the goods are afterwards immersed to produce a colored ground. Such substances are termed resists, reserves, or resist pastes, and ought to admit of being afterwards detached from the stuff by processes which will not injure the colored ground, leaving the parts which they were applied to protect either pure white or any desired shade.

Resists have been used from time immemorial in India and China, where, to produce white designs on colored goods, the practice was to trace the patterns on the white stuff in melted wax, and then to immerse it in the dye-bath, after which the goods were passed into boiling water to melt off the wax. The resists now employed are of different kinds, and may be divided into three classes—mechanical, chemical, and physical. A *mechanical resist* is any kind of preparation resembling in its operation the wax employed by the orientals, and which has the simple effect of protecting the goods from coming into contact with the dye-stuff at those parts where it is applied. A *chemical reserve* is any substance which, when printed on a stuff, without being permanently adherent to it, possesses the property either of precipitating the coloring matter or base of the mordant, and rendering it insoluble, or of altering its properties. By *physical reserves* may be understood insoluble matters, which, in contact with the fabric, absorb the mordant or coloring matter, and prevent it from penetrating the stuff. Such is the effect of pipe-clay when it is deposited upon a fabric, mixed with other substances.

But this classification of the different kinds of resists rather exhibits the different principles on which they act, than any actual division of them observed in practice. It is by the union of these principles in the same resist, just as the different styles of calico-printing are combined to produce a variegated pattern on the same stuff, that the best effect is produced. Pipe-clay, for example, is never used alone, but is mixed with mechanical or chemical resists to increase the efficiency of their action by its absorbent property. These substances may be divided, therefore, into two classes—mechanical and chemical.

1. *Mechanical Resists.*—Those of this class are termed *fat resists*, being, as might naturally be expected, chiefly of an unctuous nature, or substances having for their base resins, fatty bodies, fat or essential oils. Their indispensable property is, that they shall not dissolve in cold water, and that they shall admit of being dissolved off in hot or boiling water. Resists of this nature are chiefly employed for silk and woollen goods, or chalis, and are frequently composed of resin and suet, in the proportion of two and a half pounds of the former to one pound of the latter; or such a resist may be formed by an intimate mixture of suet and gum water. In particular circumstances, however, such resists may be applied to cotton goods. Thus, supposing that red and lilac figures have been printed on a white ground, dyed, and cleared by the madder style, these figures may be covered or overlaid with a resist consisting of suet and gum water, and the whole may then be run over with weak iron liquor for a paler lilac ground, after which the cloth is aged, dunged, re-dyed, and cleared, when the red and lilac of the pattern will be found to have been perfectly protected by the resist.

2. *Chemical Resists.*—These may be subdivided into two classes, according as their influence is exerted on the mordant or on the coloring matter itself.

The active principle of the first class, or of those substances employed to prevent the deposition of a mordant on particular parts of the cloth, is generally an acid or acidulous salt capable of uniting with the base of the mordant to form a compound soluble in water, and not decomposable into an insoluble subsalt during the hanging or ageing of the mordanted goods previous to dunging and dyeing. For the iron and aluminous mordants the resist commonly employed is lemon-juice or lime-juice, or a mixture of one of these with tartaric and oxalic acids and bisulphate of potassa. These juices are preferred to citric acid in the pure form, as the mucilaginous matters which they contain impede the crystallization of the acid within the pores of the cloth, and thus render it better adapted to prevent the attachment of the mordant in an insoluble form. The resist is seldom used of a density higher than 12° Twaddell, but its strength is regulated by that of the mordant afterwards applied. The thickening material is either a mixture of pipe-clay or china-clay with common gum, a mixture of British gum with gum Senegal, or British gum alone.

Instead of the lemon or lime juice, or a mixture of one of these with tartaric and oxalic acids, protochloride of tin—commonly called salts of tin—may be employed as a resist for iron liquor, and will prevent it from affording a deposit of insoluble subsulphate during the ageing. The protochloride of tin, however, is never applied in this way with the view of producing a white figure on a colored ground; it is commonly mixed with red liquor, as the deposition of the insoluble subsulphate of alumina from that preparation is not interfered with by the protochloride.

A solution of citrate of soda, prepared by neutralizing lime-juice of about 4° Twaddell with soda, and thickened with a mixture of gum and pipe-clay, is also much used as a resist for red and iron liquor. The principal use of neutralized lime-juice as a resist for iron liquor, is to protect figures previously applied in madder colors; for which purpose the free acid is quite inapplicable, as it would dissolve the mordant on the cloth in combination with the tinctorial matter.

The second class of chemical resists comprises those which are employed to produce a white or tinted pattern on a colored ground, by acting directly on the coloring matter itself. Such resists are chiefly employed in connection with the indigo vat, and the substances commonly used for this purpose, that is to say, to resist or modify the deposition of the indigo on certain parts of the stuff, are the sulphate and the acetate of copper, and the sulphate of zinc. Other salts of copper, and likewise the chloride of zinc and chloride of mercury, as also a mixture of the latter and biarseniate of potassa, are employed for the same purpose; but the three first-mentioned salts are those most generally applied.

A simple *white resist*, which means a resist for producing a white pattern, when the goods are to be dipped in the blue vat, may be composed as follows:—Dissolve in a gallon of water, one pound of acetate of copper, and three pounds of sulphate of copper; thicken with two pounds of gum Senegal, one pound of British gum, and four pounds of pipe-clay, adding afterwards, as a deliquescent ingredient, two ounces of nitrate of copper. When such a resist has been printed on those parts of the cloth which are not intended to absorb the indigo, the goods are suspended for one or two days, according to the composition of the resist, in a chamber which should be rather humid than too dry, and at a common temperature. The pieces are then fixed on a frame and dipped into the indigo vat, which contains in solution the colorless hydride of indigo or indigotin. The solution of indigotin is immediately absorbed by the cloth on all parts where the resist had not been printed, and these parts become deep blue when the cloth is afterwards exposed to the air, the soluble indigotin passing into the state of insoluble indigo-blue by absorbing oxygen. But wherever the resist had been applied, the solution of indigotin is not absorbed by the cloth, partly on account of the action of the pipe-clay, or the resistance of any unctuous matters which may have been added to the resist, but chiefly from the action of the metallic salt on the indigotin in solution, by which either indigotin, or else indigo-blue, becomes precipitated before the solution reaches the interior of the fibre, and when once thrown down, it is rendered incapable of being absorbed by the cloth. The indigo-blue formed by the resist, being merely attached to the surface of the stuff, is easily removed by washing.

The sulphate of zinc, when used as a resist, acts in a different manner from the sulphate or acetate of copper or the chloride of mercury. When stuffs printed with resists containing the latter are introduced into the indigo vat, the first chemical change which occurs is the decomposition of the metallic salt in the resist by the alkali or lime in the vat, whereby the cupreous salts afford a precipitate of hydrated oxide of copper, and the chloride of mercury—corrosive sublimate—a precipitate of oxide of that metal. These oxides are no sooner produced than they exert an oxidizing action on the indigotin in solution, and become reduced to the state of inferior oxides. The sulphate of zinc, on the contrary, exerts no oxidizing action on the indigotin, but causes the precipitation of that substance in an insoluble state, by withdrawing the lime which holds it in solution. This salt is used only in cases where it would not be allowable to expose the goods to dilute sulphuric acid, after having been dipped into the blue vat, as if, for instance, a design had been applied in madder colors, this operation being unnecessary with the zinc salt.

The receipt for a white resist given above is intended for a full body of blue. But the composition of the resist paste must be varied according to the depth of color in the blue ground. Thus, to compose a white reserve for light blues, dissolve in one gallon of water one pound of sulphate of copper, and four ounces of acetate of copper; and thicken, as before, with two pounds of gum Senegal, one pound of British gum, and four pounds of pipe-clay.

For protecting a design in madder colors, as well as for preserving some white, a sulphate of zinc resist may be composed as follows: Dissolve four to five pounds of the sulphate in two quarts of boiling water; with this solution, while warm, mix five and a half pounds of pipe-clay, four ounces of soft soap, and two ounces of hogs' lard, thoroughly incorporating the whole together; and, when the mixture is cold, add two quarts of gum Senegal water, containing three pounds of the gum.

A great variety of colored designs on a blue ground may be obtained by combining with the resist, either one of the saline solutions capable of imparting a mineral color, or else the mordant for a coloring matter to be applied by the madder style. As an illustration of the former, a chrome yellow design on an indigo ground may be obtained thus:—In one gallon of water dissolve three pounds of nitrate of lead, and one pound of acetate of copper; to this solution add half a pound of subacetate of lead; thicken with three pounds of gum and six pounds of pipe-clay; grind all the ingredients together, and pass through a sieve. The cloth is printed with this paste on the parts which are intended to be chrome yellow; the goods are suspended for a day or two as usual, and then dyed in the indigo vat. They are afterwards rinsed for half an hour in a solution containing five ounces of bichromate of potassa per piece of calico, and also in a bath of dilute hydrochloric acid, till the chrome yellow becomes sufficiently bright.

The second method for producing a colored figure on the indigo ground—that of combining with the resist a mordant for a vegetal coloring matter to be applied by the madder style, after the cloth has been dipped into the indigo vat—is susceptible of a great variety of modifications, and is distinguished as the *lapis* or *lazulite style*, from the resemblance of the calico thus printed and dyed to the mineral *lapis lazuli*. It is known also as the *neutral style*. As an illustration of this process, the method of producing a red figure on an indigo ground may be given:—First, to prepare the resist, six pounds of alum are dissolved in two gallons of boiling water; to this solution are added four pounds of crude acetate of lead, then four ounces of chalk, in small quantities at a time; and, lastly, six ounces of sulphate of zinc. When these materials have been thoroughly incorporated, the mixture is allowed to settle, and the clear liquor is decanted off. Then, assuming, as a standard for proportioning the other ingredients, that one gallon of the clear liquor is used, add to it three ounces of acetate of copper, eighteen ounces of gum Senegal, five pounds of pipe-clay, four ounces of soft soap, and, for sightening, a little ground indigo. After being printed with this resist, the cloth is aged for two or three days, and then subjected to the following operations:—1. Drawing by rollers *once* through the blue vat; 2. rinsing in water; 3. dunging or branning; 4. washing at the dash-wheel; 5. dyeing in the madder-beck, with from two to five pounds of madder per piece; 6. clearing, by boiling first in bran water, and afterwards in soap water.

Variously colored patterns on a blue ground are produced in a similar manner by this combination of resists with the madder style and the indigo vat.

V. DISCHARGE STYLE.—This style has many points of resemblance to the last; but there is this important difference between them, that while it is the object of the resist style to anticipate and prevent the deposition of certain colors on particular parts of the stuff, the object of the discharge style is to produce a white or colored pattern by the elimination, at determinate parts of the stuff, of a color or mordant already deposited upon it. This is accomplished by the topical application of what is termed the *discharger* to a cloth already mordanted or dyed, and is applicable to both mineral and vegetal coloring matters.

The words *white discharge*, for example, indicate an action by which a substance, printed on a stuff covered with a mordant or a color, causes the one or the other to disappear, so as to produce the design of a white figure. The essential quality of a white discharge belongs, therefore, to any substance which, either by a pure and simple combination with the matter fixed on the stuff, or by alterations which it produces upon it, brings it to such a state that not only does it cease to adhere to the cloth, but may be so completely and thoroughly washed off as to leave the white parts quite in their original state, and fitted for the reception of other colors either by dyeing or printing.

The matters capable of fulfilling such functions in all the cases that arise are not, and cannot be, of the same nature; for four general cases present themselves, each of them requiring, more or less, different properties in the discharger. According to the mordant or color employed, this discharger may be required to act on either of the following substances:—1. On a mordant or metallic oxides; 2. On organic coloring matters which have been fixed on the stuff without a mordant; 3. On organic coloring matters united to a mordant; 4. On inorganic colored compounds.

For the sake of simplicity, however, it may be sufficient to consider the subject under three heads: First, dischargers for organic coloring matters; second, dischargers for mordants; and, third, dischargers for inorganic or mineral coloring matters.

1. *Dischargers for Organic Coloring Matters.*—The two substances chiefly employed for this purpose are chlorine and chromic acid. In the article on BLEACHING, the decoloring action of chlorine on vegetal matters has been fully explained, and it is in virtue of that action that it is applied by the printer to remove vegetal colors from certain parts of the cloth. For indigo, chromic acid is chiefly employed; but for madder or other vegetal dye-stuffs fixed by a mordant, chlorine is applied to discharge or destroy the coloring principle.

A solution of the chloroxide of calcium or bleaching powder is generally employed for this purpose; but, as was explained in the article on Bleaching, this substance does not produce its effect, or acts only very slowly, except in presence of an acid to disengage the chlorine. Advantage is ingeniously taken of this circumstance by the printer, who, to produce the topical discharge of a vegetal coloring matter with which the goods have been previously dyed over the whole surface, does not apply the chlorine directly, but prints on those parts which are to be discharged a thickened acid mixture, and then passes the goods through a solution of the bleaching liquor. In this operation, the whole surface of the goods is exposed to the solution; but if the immersion is continued only for a short time, the action of the chlorine is limited to those parts which have been previously printed with the acid mixture.

It is but justice to state that this ingenious process, which deserves to rank as one of the most important discoveries in calico-printing, was invented by M. D. KŒCHLIN in 1811, and was the result of a series of elaborate researches expressly undertaken with the view of applying an effective topical discharge to Turkey-reds. It was only after attempting in vain, by a multiplicity of methods, to use the chlorine or the oxychloride of calcium *directly* as a discharger, that the happy idea occurred to this distinguished scientific printer, of first applying an acid substance, and then exposing the goods to the action of the chloride solution.

It is quite unnecessary to enter into any detail of the chemical reactions which take place in this process. These are perfectly simple, and have been already discussed in connection with the application of chlorine to bleaching in general. It will be sufficient to state that the acid applied to certain parts of the cloth combines with the base of the oxychloride, and liberates free chlorine, which exerts an instantaneous bleaching action on the vegetal coloring matter on those parts of the cloth, while the other parts remain comparatively unaffected. It is true, however, that the more delicate colors are readily discharged by the oxychloride solution alone, and, therefore, this process can only be applied for the topical discharge of fast colors, such as Turkey-red and other madder colors, and indigo.

For all madder colors except Turkey-red, a white discharger may be made by dissolving four pounds of tartaric acid in a gallon of water, mixing the solution with a gallon of lime-juice of 44° or 48° Twaddell, and thickening the mixture with pipe-clay and gum. The Turkey-red discharger requires to be somewhat stronger. It may be made by mixing four pounds of tartaric acid with a gallon of lime-juice at about 30° Twaddell, and after thickening with pipe-clay and gum, adding about a pound of concentrated sulphuric acid, or two pounds of bisulphate of potassa.

PERSOZ recommends the following as a white discharge for Turkey-red. In one gallon of water dissolve twelve pounds of tartaric acid; to this solution add eight pounds of pipe-clay, one pint of gum-water containing ten pounds of gum to the gallon, and lastly 1·7 pounds chloride of tin at 168° Twaddell. For another discharger given by the same writer, the tartaric acid is reduced to eight and a half pounds, and for a third to five pounds, the other ingredients remaining nearly the same, except that in the third the chloride of tin is omitted, and the proportion of gum water increased.

The tartaric acid in these discharges does not merely combine with the base of the oxychloride, it performs another important function by dissolving the base or mordant of the color—the iron or aluminous oxides with which the goods had been prepared to receive the color. But this is a point which will fall to be explained in treating of the dischargers for mordants.

When the goods have been printed with one or other of these dischargers, according to the fastness of the color to be destroyed, they are sometimes suspended to dry for a day or two before being passed into the oxychloride solution. But, as the tartaric acid has the property of attracting moisture even from a very dry atmosphere, the goods ought to be passed into the solution immediately after being printed with the discharger. The solution, which should not be stronger than 8° Twaddell, is usually contained in a rectangular cistern of wood, lined with lead; six or eight feet long, three feet wide, and four or five feet deep. The calico is drawn through this bath by a pair of squeezing rollers, and should not occupy more than two or three minutes in its passage. It is then put to soak in water; after which it is washed either at the dash-wheel or in the rinsing machine, and is then dried.

The only method by which chlorine, or rather an aqueous solution of chlorine, has hitherto been applied directly to the goods as a topical discharge, with any success, is by firmly compressing the cloth at those parts which it is desired to protect from the action of the decoloring agent, and leaving it uncompressed at those parts where it is intended that this agent shall penetrate. **Persoz** remarks that the idea of a process exactly the reverse of this, but the same in principle, namely, of obtaining designs or patterns by compressing the corresponding parts of a white or colored fabric before passing it into a dye-bath, is very ancient, and appears to have been first realized in India. A machine invented in Scotland has been constructed on this principle, with which, by the action of chlorine or other chemical agents exerted only on the uncompressed parts of the fabric, white or colored patterns, on colored grounds, may be produced at pleasure. This is known by the name of *Bandana printing*; being chiefly applied to the printing of white designs for handkerchiefs on Turkey-red grounds. It is in this way, indeed, that the celebrated bandana handkerchiefs have been most successfully imitated by Messrs. **Monteith** of Glasgow.

Before proceeding to explain minutely the different parts of this machine, which is one of the most ingenious contrivances connected with the art of calico-printing, a general account of its mode of action may be given, as follows:—From ten to fourteen pieces of cloth, previously dyed Turkey-red, are stretched or folded over each other quite flat and parallel, and passed together by portions at a time between two leaden plates, one of which is superimposed immediately over the other. In this way the operation advances from one end of the pieces to the other. Each of the parallel leaden plates is cut or pierced completely through, in parts exactly opposite to each other, so as to leave hollow places on all the parts required in white on the red ground. By means of a hydraulic press, the pieces of cloth are compressed between the leaden plates with a force of three hundred and twenty tons on the whole surface. While the cloth is exposed to this immense pressure, an aqueous solution of chlorine, obtained by adding sulphuric acid to a solution of bleaching powder, is made to percolate downwards through the pieces by the openings in the leaden plates. As the compressed state of the cloth prevents the imbibition of the liquid, except by the parts opposed to the design on the lead, the solution passes on in a circumscribed channel to the lower leaden plate, where it escapes, and is conveyed away by a waste-pipe. The portions of cloth through which the liquid passes are thus entirely deprived of their color. Water is then made to percolate in a similar manner to wash away the chlorine. The passage of the chlorine solution and the water through the cloth, is sometimes assisted by a pneumatic apparatus consisting of a large gas-holder, from which a current of air is forced under a moderate pressure, so as to act in the direction of the percolating liquid. It is evident that tinged liquids may be passed through in the same manner; or, after the production of a white figure on a colored ground by the action of the chlorine solution, colored figures may be applied either to the ground or to the white figure, by grounding in topical colors by the hand-block. A common method of imparting a tinted figure, is by mixing with the acid discharger one of the two solutions necessary for producing a mineral coloring matter.

If to the essential parts of the apparatus to which allusion has been made, be added cylinders for giving motion to the pieces, becks for washing them on coming out from the presses, *et cetera*, a general idea may be formed of the machine, of which the details will now be explained.

In the first place, however, it may be stated that, to render the operation continuous, a certain number of hydraulic presses are required. In the establishment of Messrs. **Monteith**, Glasgow, from which the annexed designs—Figs. 406, 407, and 408—are taken, sixteen presses are connected together in fours; and each system of four presses, with room enough between them to allow the workmen to move freely, occupies about eight yards of surface; consequently, the whole sixteen extend about forty yards in length.

A represents the capital; B, B, B, the pillars; F, the base of one of these presses; C, the upper platin, to which is fitted one of the lead plates engraved or cut through. This plate is adjusted so as to be perfectly parallel to the lower one, by means of a universal joint, and kept in its position by screws, N N. D is the lower platin or table, supporting the other engraved plate. These platins or press-plates are fitted into a strong case or frame of iron, the raised edges of which form a kind of trough or box a little larger than the leaden plate which it is intended to receive. As it is important that when the blocks approach each other to compress the folded goods between the two plates, the latter should not deviate from their position in the smallest degree, openings are made at the four corners of the frames, which fit into iron projections on the pillars, preserving their parallelism so perfectly that, if they were brought into actual contact, they would form, as it were, only one plate. E is the cylinder which, by pressing with its ram against the block, D, forces it to rise and to compress the goods placed between it and the upper block, C. G, a beck into which the goods fall after coming out of the press; *a*, *a*, tubes to allow the escape of the air from the goods and the interior of the press, when it is put into operation, and the liquid arrives at the upper surface of the plate, *m*. *b*, a tube for conducting the compressed air, which, by pressing on the mass of the bleaching or coloring liquid, forces it to pass through all the folds of the goods. C, stop-cock, by means of which either a decoloring solution, or a colored liquid, or pure water, is admitted at pleasure from the reservoir, H. *d*, *d*, graduated glass tubes which indicate the quantity of liquid contained in the reservoir, H, and consequently enable the operator to observe how much has been employed for each operation. *e*, *e*, glass stop-cocks for introducing the bleaching liquor into the reservoir, H. *g*, *g*, engraved plates fixed to the blocks, D, C.

Fig. 404.

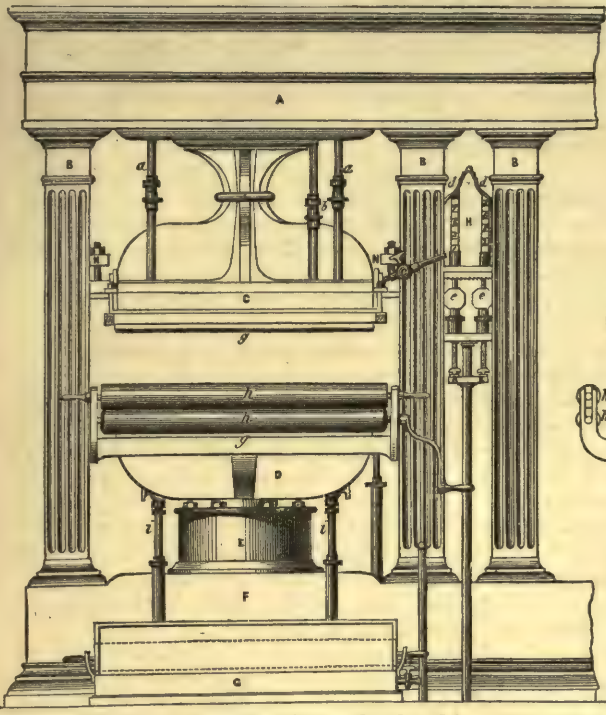


Fig. 405.

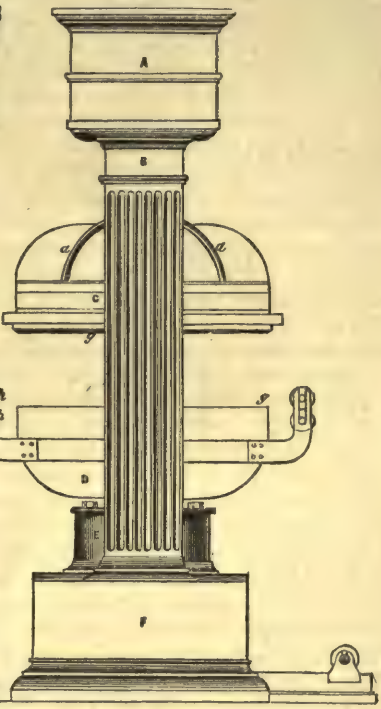
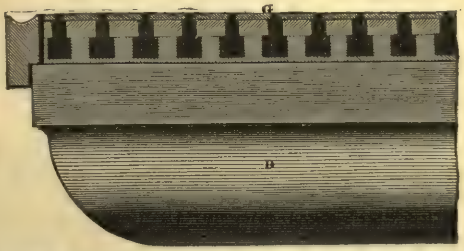
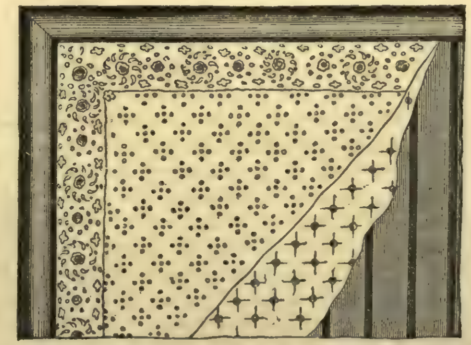


Fig. 406.



To prevent these engraved plates, which are very thin, from yielding to the pressure and being put out of shape, they are soldered by the edges to a leaden plate nearly half an inch in thickness, and pierced with a multitude of small holes to allow the air and the liquid to pass freely through the openings which do the work of the engraving. To the edges of this plate of lead is soldered a sheet or rim of the same metal, which, rising over the edges of the frame, keeps in the liquid intended to pass through the goods. One of the engraved leaden plates, so adjusted, is represented in the annexed engraving—Fig. 407.

Fig. 407.



The preparation and engraving of the plates are very simple. After being hammered out, they are smoothed with the plane, and a paper containing the design to be engraved is glued or pasted upon them.

The outlines of the figure are then sketched on the metal with a tracing point, and the operator has only to work out with the graving tool or chisel all the parts that are to be removed or left void. Then, as the second plate must correspond to the first with mathematical precision, the latter is covered with printing ink and applied to the other, when the two are submitted to the action of a press. A perfect pattern of the first plate is thus reproduced upon the other, and this has only to be carefully cut out.

m, *m*, projecting edges, pierced with holes three or four inches in depth, to which correspond iron pins placed on the lower frame, to maintain the most perfect parallelism between the plates while they are approaching each other. *h*, *h*, cylinders for passing out the pieces from the presses into the becks, which are filled with water by the stop-cock, *s*. *i*, *i*, tubes by which the liquors and water flow after passing through the goods.

When the printing is about to be proceeded with, the pieces, about fourteen in number, as already stated, are unrolled from a wooden cylinder by a workman, who, with the assistance of hooks fixed at the four corners of the press-table, folds the goods very regularly on the lower plate. This operation being finished, a first movement given to the presses suddenly raises the block, D, towards C; a second movement gives the goods the pressure required, and then, by a turn of the stop-cock, the liquids to be passed down through them are let out from the cistern, H. The power is applied by hydraulic presses, which may be stationed outside the printing room. The stop-cocks, *a*, *a*, are first opened to allow the air to escape; then the stop-cock, C, through which the liquid flows and penetrates the impressed parts of the stuff, passing through the openings in the block, and on the upper plate, C. When these parts are filled with the fluid, the stop-cocks, *a*, *a*, and C, are closed, and the stop-cocks, *b*, *b*, opened, to give access to the column of compressed air, which forces the liquid through the goods in the direction cleared for it in the openings of the engraved lead plates, *g*, *g*, and finally through the tubes, *i*, *i*, into a cistern placed at the foot of the machine.

By exactly the same process, several liquors may be passed through the goods in succession, either to bleach, or color, or wash them; but as it often happens that the column of compressed air does not exercise sufficient force to cause the liquid to pass through as quickly as may be desired, the force of the air is increased by applying additional pressure to the air cistern. As soon as the liquid has produced its effect, and the goods have been washed with the water passed through them by the same means, the washing is completed by immediately emptying them into the water beck placed at the foot of the apparatus.

It has been stated, that the only substance besides chlorine which is commonly employed as a discharge for vegetal coloring matters is chromic acid, and that this substance is generally applied in connection with the indigo vat. Like chlorine, however, the chromic acid cannot be conveniently or safely applied directly to the cloth, and therefore was comparatively useless for this purpose till the following method of using it with safety and success was discovered by Mr. JOHN MERCER of the Oakenshaw Print Works, near Accrington, about the year 1826. This discovery is usually ascribed to the late Mr. THOMPSON of Clitheroe, but the Editor has evidence in his possession that the process was first practised by Mr. MERCER.

The cloth being dyed with indigo in the usual manner is padded with a solution of bichromate of potassa, containing about eight ounces of the salt to the gallon of water. This operation, as well as the subsequent drying of the goods, must be performed in a dim light, for the instant effect of a strong light would be to destroy the beauty of the blue color, and even to injure the cloth itself. The goods are sometimes dried in the shade at the ordinary temperature; but PERSOZ recommends an immediate and rapid desiccation in the hot stove. The cloth is then printed with a discharger containing tartaric acid, oxalic acid, citric acid, and sometimes hydrochloric acid. PERSOZ, however, suggests for roller-printing the following, containing only oxalic and sulphuric acids:—In two-thirds of a gallon of boiling water, dissolve two pounds of oxalic acid; to the remaining third, add seven and a half pounds of roasted starch, twelve and a half pounds of sulphate of lead, and 1·28 pounds of sulphuric acid; then mix the whole. When the cloth has been printed with this discharger, it is immediately winced in water containing some chalk in suspension; then rinsed at the dash-wheel, passed through dilute sulphuric acid, and, lastly, washed in clean water.

The discharger is no sooner applied to the cloth in this process, than the color of the indigo is destroyed, chromic acid being then liberated from the bichromate through the superior affinity of the acids in the discharge paste for the potassa, and the free chromic acid at once oxidizes and destroys the coloring matter. To produce a yellow instead of a white figure by this process, the acid discharger, says PARNELL, may be mixed with a salt of lead; but sulphate of lead forms a very large constituent in PERSOZ' recipe, above quoted, for a white discharge.

2. *Dischargers for Mordants.*—Instead of waiting till the goods have been mordanted and dyed, and then applying a discharger which shall combine elements both for destroying the color and dissolving off the mordant, it seems to be a shorter and more direct method to apply the discharger on the mordant, and then to dye the goods, in which case the coloring matter will only adhere to those parts on which the discharger has not been applied. The name of the *discharge* or *rongeant* style is exclusively applied by some writers to this process of removing the mordant previous to the application of the coloring matter, while the method of applying chlorine or other substances to act directly upon the tinctorial matter itself, is termed the *enlevage* or *decoloring* style. Both, however, are equally discharging processes, and when it is considered that compound mineral colors are really composed of ingredients which act as mordants to each other, there seems to be no substantial foundation for this distinction of styles.

The substances employed for dischargers of mordants must be such as shall be capable of combining with the metallic oxides which constitute the bases of these mordants, while, at the same time, the combination so formed shall not itself act as a mordant. Three organic acids—the tartaric, the citric, and the oxalic—are chiefly employed for this purpose. Some inorganic acids, such as the sulphuric, the nitric, and the hydrochloric, would act with greater energy, but would destroy or injure the fabric. It is chiefly to produce white or colored figures on grounds of madder and logwood, that the three organic acids above mentioned are applied to discharge the iron or aluminous mordants before dyeing the goods. Instead of the pure citric acid, however, lime or lemon juice is always preferred, for the reason already stated. To discharge the mordant from a piece of cloth impregnated with red liquor of specific gravity 7° Twaddell or weaker, or with iron liquor at 2° Twaddell or weaker, the following mixture may be used—namely, one gallon of lime-juice of specific gravity 6° Twaddell, three and a half ounces of oxalic acid, and four ounces of tartaric acid. If this mixture is to be applied by the block, it may be thickened with pipe-clay and gum, or with British gum if by the roller. It may be remarked, that whenever the two last mentioned acids are used, they should always be accompanied by treacle.

To procure a white design on a black ground by the discharge of the mordant, the cloth may be treated in the following manner:—1. Pad or print the calico with a mixture of equal measures of iron liquor of 6° Twaddell, and red liquor of 8° Twaddell, thickened with starch or British gum; 2. Dry over the steam-boxes, age, and apply a discharger composed of tartaric acid, sulphuric acid, and lime-juice, thickened with British gum; 3. Pass the cloth through warm water mixed with chalk; 4. Dye in decoction of logwood mixed with a little bran and dung; 5. Wash, clear the white by branning, rinse, and dry.

The action of these organic acids in discharging mordants, will explain their application in connection with chlorine and chromic acid, for discharging coloring matters which have been fixed by mordants.

3. *Dischargers for Mineral Colors.*—Mineral colors are discharged on precisely the same principle as the mordants, and here also the same organic acids are largely employed. Thus, to obtain a white figure on a ground of iron buff, a mixture of tartaric and oxalic acids with lime-juice thickened with pipe-clay, or China clay and gum, is applied to the cloth. The base of the buff color is sesquioxide of iron, which is dissolved by the acids, and the figure is obtained perfectly white by washing. This case, indeed, may afford a good illustration of the analogy between the discharging of mineral colors and of mordants properly so called, for the readiest way of discharging the iron is to apply the acid mixture after the cloth has been padded in the buff liquor, and before it is exposed to the soda solution to precipitate the sesquioxide of iron.

Again, to produce a white figure on a ground of prussian blue, the cloth is printed with a paste containing a caustic alkali, and afterwards passed through a solution of oxalic acid. In this case, the prussian blue is first decomposed by the alkali, affording either yellow prussiate of potassa or prussiate of soda, while sesquioxide of iron is precipitated on the cloth. The latter is dissolved out by the oxalic acid, while the alkaline salt is removed by washing.

A beautiful chrome yellow discharge is obtained by dissolving litharge—oxide of lead—in tartrate of potassa and soda, with excess of the latter, thickened with gum tragacanth. After printing, expose to the atmosphere; the lead soon becomes carbonated; wash off and dye in bichrome with a little nitric acid.

Any substance may be employed, however, which will have the effect of decomposing the mineral color, and of forming with its constituents new combinations which shall be either colorless, or capable of being washed off. The proper discharger for a mineral color of which the composition is known, is, therefore, a purely chemical problem in the strictest sense of the words. Thus, a white figure may be produced on a ground of manganese brown or bronze, by simply printing on the cloth a slightly acid solution of protochloride of tin, containing one and a half, or two pounds, of the protochloride per gallon, and thickened with about a pound of starch to the gallon. The brown coloring matter is known to consist of binoxide of manganese, which is decomposed by the protochloride of tin, and converted into the soluble protochloride of manganese, while binoxide of tin is precipitated on the cloth. Thus the conditions of the two compounds are exactly reversed. The binoxide of manganese is converted into the protochloride, and the protochloride of tin is converted into the binoxide, as shown in the annexed equation:—

$$\underbrace{\mathrm{Mn\,O_2}}_{\text{Binoxide of manganese.}} + \underbrace{\mathrm{Sn\,Cl}}_{\text{Chloride of tin.}} = \underbrace{\mathrm{Sn\,O_2}}_{\text{Binoxide of tin.}} + \underbrace{\mathrm{Mn\,Cl}}_{\text{Chloride of manganese.}}$$

The new manganese compound is easily dissolved off by washing, and the oxide of tin being white, although it adheres to the cloth, produces the kind of figure desired.

Generally, in such cases, the printer has in view the production of a white figure, with a view to the subsequent deposition of another color upon it different from that of the ground. In such cases the binoxide of tin, already formed on the pattern, acts as a mordant for certain vegetal dyestuffs, such as logwood or quercitron, the coloring principles of which may be applied afterwards. Or these may be printed on the cloth along with the tin, and their corresponding mordants. Thus, to impart a design in white, blue, and yellow on the same bronze ground, the cloth on which the manganese has been raised may be printed with the salts of tin for the white; with a mixture of berry liquor, alum, and salts of tin for the yellow; and with a mixture of salts of tin, prussiate of potassa, nitrate of sesquioxide of iron, hydrochloric acid, and British gum for the blue, using, of course, as many different blocks or rollers. It may be added, that protochloride of tin, when mixed with sulphuric and tartaric, or oxalic acid, is also used as a discharger for chrome-yellow and chrome-orange.

VI. CHINA BLUE STYLE.—Prior to MR. MERCER'S discovery of the method of applying chromic acid as a discharger, the only means generally employed for producing a white or light-colored figure on indigo blue grounds, was either by the topical application of resist pastes, or by that peculiar process termed the *China blue style.* This is an interesting modification of the topical style, practised only with indigo, and by which a pattern is formed, consisting partly of white, and partly of different shades of blue. Its peculiarity consists in this, that whereas in the common process of dyeing with the indigo vat, the insoluble indigo-blue is hydrogenized or deoxidized, and converted into soluble indigotin in the vat, this process, in the China-blue style, is effected upon the cloth itself. The insoluble indigo is first printed upon the cloth, mixed with certain ingredients, and then it is reduced to the soluble state and washed into the pores of the stuff by a series of alternate immersions in alkaline and iron solutions. What is remarkable about this process is the fact, that the different shades of blue should thus be dissolved upon the fabric, so as completely to penetrate its texture, without intermixing with each other, staining the parts left white, and blending, in short, into one uniform blue ground.

This is by no means a new process; on the contrary, it seems to have been discovered and practised at a very early period in the history of calico-printing, and long before any correct idea could be formed of the chemical reactions which take place. **PERSOZ** states that he has in his possession specimens of this kind of printing, which must have been executed nearly a century ago; but he shows that prior to 1780, if not down to a later period, goods were never printed in this manner with more than one shade of blue. The same writer justly remarks, that he must have been either a bold man, or a person possessed of knowledge in advance of his age, who, to combine indigo with the stuff, did not hesitate to render soluble upon that stuff, in presence of a liquid, the substance which he had deposited upon it in an insoluble state; for, without having tested the fact by experience, it was natural to expect that the liquid would thoroughly dilute the color as soon as it became soluble, and render impossible the realization of any design whatever.

The details of the process adopted in this style of printing are as follow:—The indigo is first coarsely ground, and then mixed with other ingredients in the proportions subjoined:—

16 pounds of indigo,
4 pounds of orpiment—sulphide of arsenic,
22 pounds of copperas—sulphate of iron, and
10 gallons of water, or water and gum-water.

The whole of the water is not added at once. The indigo, sulphide of arsenic, and sulphate of iron, are ground together in a mill for three days with five gallons of water. The mass is then removed, and the mill is washed with a gallon of water, which is added to the mixture; the remaining four gallons of water, or, if a very thick blue is required, as many gallons of strong gum-water, are afterwards introduced. The different shades of blue are produced by diluting this mixture with different proportions of water or gum-water. It is evident that the mere addition of gum, when the same quota of water is used, does not alter the depth of the shade, but merely the thickness or consistency of the color. Assuming, therefore, as the unit or standard the mixture formed with the quantity of water or gum-water above-mentioned, and calling this No. 1 in the following table, the other numbers will serve as a reference for lighter shades, procured by diluting the standard mixture with certain measures of water or mucilage in the proportions stated:—

Course of Shades.	Quantity by measure of No. 1.	Quantity by measure of water or mucilage.
No. 1	1	0
" 2	11	1
" 3	10	2
" 4	8	4
" 5	6	6
" 6	4	8
" 7	2	10
" 8	2	12
" 9	2	14
" 10	2	16
" 11	2	18
" 12	2	20

In this table, constructed by M. **THILLAYE**, the printer is furnished with the requisite proportions of water or gum-water, for twelve different gradations of blue, proceeding from the original mixture, No. 1, which is almost black, to a shade in which that mixture is diluted with ten measures of water.

For a pattern in China blue, to consist of one, two, three, or any number of these shades, associated with white, the proper shades are selected, and the color, suitably diluted and thickened, is printed on the stuff with a separate block or cylinder for each shade. Thus, for the impression of a single blue, with small dots, No. 5, thickened with starch, may be printed by the block, or No. 4, thickened with gum, by the cylinder; for an impression of two different blues with the block, No. 4 with starch, and No. 9 with gum; for an impression of three blues with the block, a good combination is formed by No. 5 with starch, No. 7 with starch, and No. 10 with gum.

After being printed, the calico is suspended in a moderately dry and airy apartment for a day or two, and is then dipped in a certain order into three vats, which may be distinguished as the lime, the iron, and the soda vats, and are composed as follows:—

Lime Vat	containing	100 pounds of lime to 600 gallons of water.
Iron Vat	„	solution of sulphate of iron of specific gravity 1·048.
Soda Vat	„	solution of caustic soda of specific gravity 1·055, made from soda crystals, quick-lime, and water as usual.

For immersion in these vats, the goods are stretched in perpendicular folds on a rectangular wooden frame, suspended by pulleys from the ceiling of the apartment. The vats consist of three adjacent stone cisterns, the tops of which are on a level with the ground, and their usual dimensions are eight or nine feet in length, four in depth, and three in width. The frame with the cloth is then dipped into these vats or cisterns in the following order, *continuing each immersion for ten minutes, and draining for five minutes after each dipping.* 1. In the lime vat; 2. In the iron vat; 3. In the lime vat; 4. In the iron vat; 5. In the soda vat; 6. In the iron vat; 7. In the lime vat; 8. In the iron vat; 9. In the lime vat; 10. In the iron vat; 11. In the soda vat.

Allowing to each of these immersions and subsequent drainings the time above stated, the whole operation, assuming no time to be lost, will occupy about three hours. When submerged in the lime vat, a gentle swinging motion is communicated to the frames; and, after the last dip and draining are given, the calico is plunged, upon its frame, into a fourth similar vat, containing sulphuric acid, of about the specific gravity 1·025, or 5° Twaddell. This is for the purpose of removing the oxide of iron deposited upon the calico in the alternate passages through the sulphate of iron and lime vats. The goods are then rinsed in running water, and finally brightened by a second immersion in the above diluted sulphuric acid, slightly tepid. Sometimes the clearing of the white ground is completed by exposing the cloth to a soap liquor at the temperature of 120°.

Having thus stated the details of the different ingredients and operations required, it may be observed that the theory of the process admits of satisfactory explanation by the light of modern chemistry. The cloth, in the first place, is simply printed with a pigment consisting of insoluble indigo-blue, mixed with sulphide of arsenic and sulphate of copper. When this is dipped into the first vat containing lime, a film of the sulphate of iron is decomposed, its sulphuric acid combines with the lime, and protoxide of iron is liberated, which deoxidises a film of indigo, thereby rendering it soluble in lime-water. In this state it penetrates the fibre, and on exposure to air during the subsequent draining absorbs oxygen, so as to become insoluble and fixed within the pores of the stuff. On dipping the calico into the second vat, containing sulphate of iron, a layer of oxide is formed on its surface by the action of the lime-water which remains on the stuff, and this oxide deoxidises another film of indigo, which is dissolved by a second immersion in the lime vat. Thus, the successive films of indigo are deoxidised, dissolved into the stuff, and re-oxidised; producing a progressively increasing fixation of indigo within the fibres. The frame is shaken in the lime vat to detach the deposit of sulphate of lime which falls upon the cloth, but it is kept motionless in the copperas bath, to favor the deposition of as much protoxide upon it as possible.

It will be observed that in this theory of the process, which is, upon the whole, satisfactory in a general way, the presence of the orpiment or sulphide of arsenic has not been recognised at all. PARNELL remarks that it seems to act chiefly by increasing the density of the mixture, thus preventing its ready disintegration and removal by the various liquids to which the cloth is exposed; and that it also assists, probably, in deoxidising the indigo-blue in conjunction with the lime. PERSOZ, however, in different receipts which he gives for China blues, omits the orpiment entirely, and, as it appears to be difficult to see how it can really exert a beneficial action, perhaps it might be wholly dispensed with. Thus, for a blue to be printed by the roller, PERSOZ gives the following ingredients:—

17·5 pounds indigo,
17·5 pounds sulphate of iron,
5·5 gallons of water; thickened with
33 pounds gum arabic.

Another receipt which he gives for printing with the block is as follows:—To a gallon of water add one quart of honey, eleven ounces of pulverized indigo, eleven ounces of sulphate of iron, and thicken with one pound of starch.

The mixture which was mentioned first of all, and to which M. THILLAYE's table of twelve gradations is adjusted, differs considerably from that which is commonly employed in this country. English printers, instead of the sulphate, generally use the acetate of iron —iron liquor—and British gum, in lieu of common gum. Employing these ingredients, the following proportions are given by PARNELL as forming a suitable mixture:—

16 pounds of ground indigo,
5 or 6 gallons of strong iron liquor,
2 pounds of orpiment, and
8 gallons of water thickened with British gum.

He gives also the subjoined table of the proportions of water or mucilage with which this mixture, containing two pounds of indigo to the gallon, may be diluted to furnish, along with the original mixture itself, eleven shades or gradations:—

No.	Quantity by measure of above mixture.	Quantity by measure of water or gum-water.	Quantity of indigo in one gallon of the mixture.	
			lbs.	oz.
1	1	0	2	0
2	1	½	1	5¼
3	1	¾	1	3¼
4	1	1	1	0
5	1	2	0	10¾
6	1	3	0	8
7	1	5	0	5¼
8	1	7	0	4
9	1	9	0	3⅕
10	1	12	0	2½
11	1	16	0	1¼

COMBINATION OF DIFFERENT STYLES.—All the preceding styles are practised in printing cottons or calicoes, and most of them apply, with certain modifications, to the printing of woollens, silks, and mixed stuffs. On the other hand, the peculiar process termed the *mandarining style*, is applicable only to silks, woollens, and chalis, or stuffs that are composed entirely of animal fibre, and therefore, before proceeding to explain it, some account may be given of the principal modifications required in applying the styles already enumerated to fabrics of that description. At the same time, before concluding the subject of calico-printing, properly so-called, one or two illustrations may be given, to show how the different styles are usually combined, in producing a variegated design on the same piece.

To produce a pattern, for example, in black, red, brown, green, and yellow on a white ground, the following process may be adopted, which is susceptible of a great variety of modifications, and is a combination of the madder style with a topical brown and with steam colors:—First, the cloth is printed by the three-color machine in the following manner: with iron liquor, for black, by the first roller; with red liquor by the second roller, and with catechu brown by the third roller. The cloth is then aged for two days, dunged, dyed in the madder beck, and cleared. Lastly, it is printed or *grounded in* by the block with the mixtures for steam-green and steam-yellow; then steamed, aged, and washed.

By a similar series of operations, a design may be imprinted in black, brown, lilac, pink, green, blue, orange, and yellow, on a white ground. The cloth, in this case, is first printed by the four-color machine, with iron liquor of two strengths, one for the black, the other for the lilac; with red liquor for the pink, and with the mixture for catechu brown. After being aged, dunged, dyed with madder, and cleared as usual, the cloth is printed by the block with the mixtures for steam-blue and steam-yellow, and then steamed in the ordinary manner. To produce the orange, the steam-yellow is printed on a part of the pink, and the green results from the mixture of some of the yellow with the blue.

Again, the following method of procuring a design in black, purple, two shades of red, two shades of buff, green, and yellow on a white ground, is an example of the combination of mineral colors with madder and steam colors topically applied:—In the first place, the cloth is printed by the four-color machine with the mordants for black, purple, and two reds; it is then aged, dunged, dyed in the madder beck, cleared, and dried. It is next printed either by the two-color machine or by blocks, according to the design, with buff-liquor of two strengths, thickened with starch or British gum; then aged, rinsed in milk of lime to raise the buff, rinsed and dried. Lastly, it is printed by blocks with the mixtures for steam-blue and steam-yellow, aged, steamed, and rinsed.

It is evident that the resist and discharge styles may be combined with these or similar processes, to give still greater variety to the pattern; so that, to procure a single variegated design, almost all the different styles enumerated may be applied simultaneously or successively to the same fabric; and it is by their skilful combination that the ingenuity of the calico-printer is displayed, and those wonderful results are produced which exhibit the boundless resources of his art, and constantly astonish and fascinate the world with striking novelties, which, in their endless variety, almost rival the kaleidoscope.

PRINTING OF WOOLLENS, SILKS, AND MIXED STUFFS.—The calico-printer has not often to practise his art on linen goods, or on fabrics of mixed cotton and linen; and when, in particular cases, he requires to do so, he operates on vegetal fibres of nearly the same character and constitution in both cases, so that the processes already described may be regarded as applicable either to cottons or linens, or fabrics in which the two are combined. The case is somewhat different, however, when he wishes to imprint a pattern on a tissue composed of the animal fibre, which manifests a much stronger affinity for most colors, and which, in some important particulars, requires a considerable modification in the manner of treatment. This animal fibre, moreover, according as it presents itself in the shape of wool or silk, renders necessary some distinguishing peculiarities in the mode of treatment; and when, again, woollen or silk fibres are combined with cotton or with each other in the same stuff, a still further modification is required to adapt the relations of the coloring matters and mordants to the mixed fabric.

As a general rule, the madder process, which is so extensively employed in the printing of calicoes, cannot be conveniently applied to the animal fibre, because it involves, in one part of the operation, the total immersion of the goods in the dye-stuff, which, in the process with calicoes, is afterwards easily washed off, except where the mordant has been applied; but such is the attraction of the animal fibre for coloring matters, that even where the mordant has not been applied, the color strongly adheres, and, in the case of woollen goods in particular, the fabric cannot be restored to its original purity. In some processes of silk printing, the madder style is applied; but not without much difficulty and precaution. No mineral coloring material, except prussian blue, is applied to silks or woollens; and hence, in default of having recourse to the madder style, the fixation of the colors imprinted on these tissues can only be effected, in general, by the process of steaming.

Till lately, the printing of silken and woollen stuffs, delaines, chalis, and other mixed fabrics, was confined to the block; but the great extension which has been given to this department by the discovery and improvement of the steaming process, as well as by the great improvements effected in cylinder-printing, has led to the general substitution of the latter method. The press machine and the perrotine are also largely employed in printing these fabrics. They are generally steamed with the lantern, the drum, or the chamber, in which the different parts of the goods are preserved from contact with each other, whereas, in steaming with the column, the fabric is coiled upon itself. In the steaming of calicoes, this is generally attended with no inconvenience, but the fibres of wool and silk have too much attraction for the colors to be treated in the same manner without contracting folding stains, or as the French writers express it, *rapplicages*.

Having made these general remarks with reference to the application of the processes of calico-printing to stuffs consisting, either wholly or in part, of the animal fibre, the Editor will now proceed to point out very briefly, the principal modifications of treatment required for each in particular—namely, first, for woollens; second, for a mixture of wool and cottons, such as delaines; third, for silks; and lastly, for chalis, or a mixture of wool and silk.

Printing of Woollen Stuffs.—The great attraction which the fibre of wool has for coloring matters, while, on the one hand, it renders the madder process inapplicable to woollen stuffs, enables the printer, on the other, to dispense with that preliminary mordanting which is in general given to calicoes, even to prepare them for steam-colors. The very same circumstance, however, requires that the greatest care should have been taken in the bleaching or sulphuring of the wool, and more especially in the *azuring* which constitutes a part of that process. If salts of copper or tin are present, these will infallibly combine, under the action of the steam, with the sulphur adhering to the wool, unless it has been bleached in the most perfect manner, and spots or discolorations will be found after the steaming, which will be ruinous to the whole process. The printer's attention is therefore directed to the method of bleaching woollen goods, described at page 325, as particularly adapted for goods intended for very delicate printing. CHEVREUL has clearly established that the spots or stains so often observed on woollen stuffs after the steaming, are generally due to the presence of a compound of copper, or, more rarely, to that of a compound of tin with the sulphur of the wool, and that these stains are developed during the steaming, by the mutual action of the wool and a salt of copper in presence of steam.

The quality of the sulphate or acetate of alumina, which is the base of many steam-colors, must also be taken into consideration. Sometimes ordinary alum is used, sometimes acetate of alumina; and though it is of little importance in the printing of calicoes whether the acetate of alumina has been prepared directly, or by the double decomposition of alum and acetate of lead, it is different in the printing of woollen goods; for that which is derived from the acetate of lead, *always retains a certain quantity of the sulphate of lead*, which, according to the nature of the color, may act on the wool, and give it a brown tint, by reason of the sulphur which it contains. PERSOZ, proceeding on certain experiments made by himself, strongly advises the printer to use only pure alum, and to add, in the cold, to each thickened color, the quantity of acetate of potassa, soda, or ammonia, necessary to render the alum cubical, and capable of yielding its base to the stuff by the effect of temperature alone. He says it is best to employ the acetate of ammonia in all cases where the color is not acted on by the ammoniacal salts, and the acetates of potassa and soda in all other cases.

But the principal difference between the printing of woollen and cotton goods, consists in the composition of the coloring mixtures applied. The woollen fibre resists the action of acids better than cotton, and hence in the mixtures for steam-colors for woollen goods a greater proportion of free acid is introduced, which has the effect of dissolving the lake, or the oxide of the mordant, and thus of producing a more intimate and more uniform fixation, imparting at the same time a higher lustre to the shades. It is for this reason that in mixing steam-colors for woollens, a considerable quantity of tartaric or oxalic acid is almost always employed, whether the mordant mixed with the color is perchloride of tin, protochloride of tin, or alum. At the same time, it is certain that even insoluble bodies, such as charcoal powder, often adhere firmly to wool, and dye or stain it a durable and brilliant color without undergoing the process of solution at all. The most vivid colors on wool are generally obtained by protochloride of tin, with either oxalic or tartaric acid. To show the composition of the mixtures for such colors, a few examples may be given.

The *reds* for woollen stuffs are all formed with cochineal and preparations of tin. Thus for a poppy-red, take one gallon of cochineal liquor, made with two and a half pounds of pulverized and prepared cochineal; thicken, hot, with a pound and a quarter of starch, and while still tepid, add half a pound of oxalic acid, and one pound of a composition formed by adding two ounces of tin to nine ounces of hydrochloric acid mixed with five ounces of nitric acid.

For a *fine red*, PERSOZ gives the following:—Boil for five minutes in one gallon of water five pounds of crushed cochineal; thicken with half a pound of starch, and when the mixture has been well boiled, withdraw it from the fire and dissolve in it one pound of oxalic acid, and ten ounces of gum arabic; when cold, add seven ounces of chloride of tin at 106° Twaddell.

Steam-yellows for woollens are formed like the yellows for calico, by decoctions of Persian berry, quercitron, or weld, and have generally the oxide of tin along with alumina for their base. Thus, for an orange yellow, take one gallon of decoction of Persian berries at 14° Twaddell; thicken with two pounds of starch, and add to the mixture ten ounces of alum, eight ounces of chloride of tin, and two and a half ounces of oxalic acid.

Two kinds of *blue* are in use for printing on woollen stuffs; the one formed with carmin of indigo—soluble indigo—the other with the ferrocyanide of potassium. Both have alumina for their base, and to promote its solution not only oxalic acid, but likewise a certain proportion of tartaric acid is introduced. To fix prussian blue on wool, the red cyanide is decomposed by a suitable proportion of tartaric acid to set free the cyanide of iron, and a preparation of tin is added, the object of which is not so much to fix the color, as to give it that fine shade known by the name of *royal blue.*

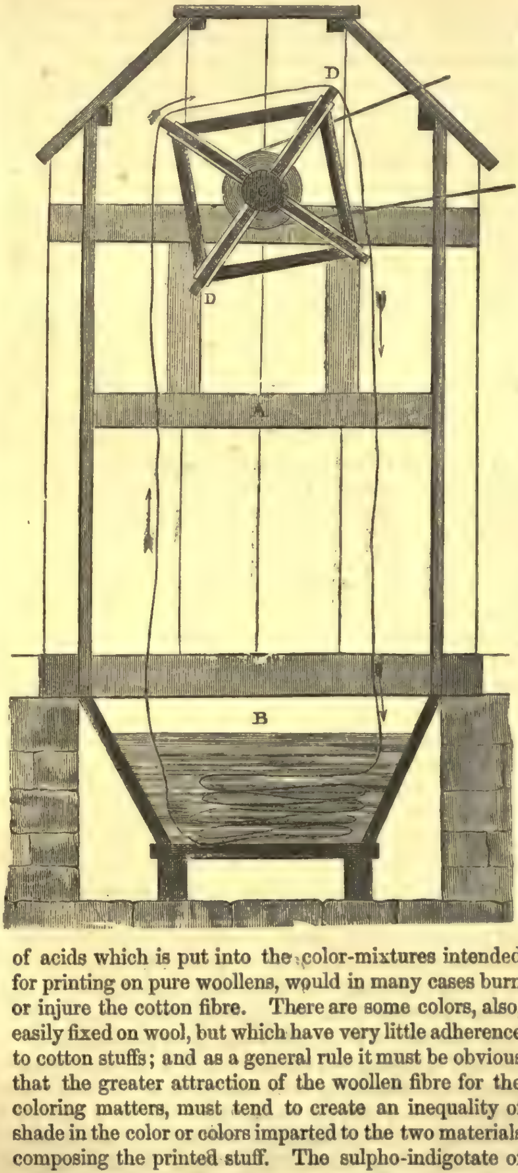
For a good *indigo-blue*, dissolve in one gallon of warm water five ounces of the soluble indigo of commerce; thicken with three and a half pounds of gum, add four ounces of alum, five ounces of oxalic acid, and three ounces of tartaric acid.

For a *prussian blue*, in one gallon of water dissolve twelve ounces of alum, and one pound of oxalic acid; thicken with seven and a half pounds of gum, then add to the tepid mixture half a pound of chloride of tin, two and a half pounds of ferrocyanide of potassium, and twelve ounces of nitrate of iron at 76° Twaddell.

Woollen goods are sometimes steamed at two operations, to prevent the flowing of the colors by a too prolonged exposure to the aqueous vapour; but goods printed with detached figures, are generally exposed to a single steaming of forty to fifty minutes' duration. The washing and drying of the woollen stuffs, after being printed and steamed, are two operations requiring some management. The ordinary washing machines soak the goods too much, and render the subsequent drying too slow. The best method is, to subject the goods to a rapid wincing in a bath fitted with a reel like that of the ordinary dye-beck, and capable of receiving a very rapid motion. This arrangement is represented in the annexed engraving—Fig. 408. A, is a wooden frame supporting the axis, C, of a reel, D, D, which is put in motion by a pulley at one of its ends; B, a trough filled with water, or, better still, a vessel or compartment placed in running water. The goods being formed into an endless web, are passed over the reel, and the whole apparatus is covered in, so that the water which is thrown off by the very rapid motion of the reel, falls back upon the stuff and promotes the washing. The goods are then rapidly dried by means of the hydro-extractor.

Fabrics of mixed Cotton and Wool.—The printing of the stuffs termed *delaines*, which are formed of a mixture of cotton and wool, presents a problem of greater difficulty than is involved in the printing of either of the fibres separately. This will be obvious when one considers that the composition or mixture of the colors which is most suitable for cotton is less adapted for wool, and, on the other hand, the quantity of acids which is put into the color-mixtures intended for printing on pure woollens, would in many cases burn or injure the cotton fibre. There are some colors, also, easily fixed on wool, but which have very little adherence to cotton stuffs; and as a general rule it must be obvious that the greater attraction of the woollen fibre for the coloring matters, must tend to create an inequality of shade in the color or colors imparted to the two materials composing the printed stuff. The sulpho-indigotate of potassa, or soluble blue of commerce, affords a striking example of a color, which, when printed on delaines, communicates a strong shade to the wool, but only an imperfect coloration to the cotton contained in the fabric; and the mode in which this inequality is corrected, will show how the difficulty is surmounted in most cases. It consists in mixing with the indigo-blue for the wool, a suitable proportion of steam-blue for the cotton, prepared by a mixture of yellow or red prussiate of potassa with tartaric, oxalic, or sulphuric acid, and alum. In one peculiar style of fancy dyeing, the woollen thread only is dyed, and the cotton is afterwards perfectly bleached by exposing the dyed delaines to a dilute solution of bleaching powder.

Fig. 408.



It has been stated, that cotton goods are generally prepared for steam-colors by a previous mordanting—a preparation which is not required for woollen goods. Delaines, however, are always prepared in this manner, on account of the cotton which they contain, and which, by this preliminary process, is rendered more apt to receive and to retain the colors like the wool itself. These stuffs, before being printed, are always impregnated with binoxide of tin, from the different solutions applied consecutively. They ought, also, to be perfectly bleached before receiving the mordant, for otherwise the white parts remain dull, and produce inequalities in the shades. The usual preliminary process with these mixed fabrics, is to pass them on rollers through a cistern charged with a solution of bleaching powder and a little sulphuric acid. The woollen fibre is thus made to combine with as much chlorine as possible, so as not to brown it. The stuff is then impregnated with stannate of soda, and run through *dilute* sulphuric acid to fix the oxide of tin. The perfection of the work depends chiefly on this process.

The steaming is performed in the same manner as for woollens, and either by the column or chamber, but generally for a shorter period. This is a point, however, for which it is impossible to lay down any fixed rule, as the time must vary according to the manner in which the steam is applied, the dimensions of the chamber, and the quantity of acid in the mixtures. With a considerable quantity of acid, such as is best adapted for woollen stuffs, the fibres of the cotton especially become weakened by too long exposure.

The following receipt is given by PERSOZ for an *amaranth* mixture, suited to this kind of fabric:—Boil two and a half pounds of powdered ammoniacal cochineal in a gallon of water; thicken with two pounds thirteen ounces of gum-Senegal; add half a pound of alum, and two pounds of bichloride of tin at 125° Twaddell. This amaranth is also adapted for cylinder-printing on wool.

For a *Turkey yellow*, take a decoction of three pounds of Persian berries in a gallon of water; thicken with fourteen pounds of starch; boil and add one pound of protochloride of tin.

For a *dark double blue*, dissolve in one gallon of warm water two and a half pounds of ferrocyanide of potassium; add, when tepid, six ounces of oxalic acid, and seven ounces of alum; thicken with one gallon of gum-water containing eleven pounds of gum, and to which has been added five pounds of soluble indigo-blue.

Printing of Silk stuffs and Chalis.—The printing of steam-colors on silks, is similar to printing on woollens, except that the acids must be used more sparingly. In this respect, indeed, the composition of the color mixtures for silks, is more analogous to that which is required in calico-printing; but, on the other hand, the silk and the wool have similar relations of affinity for the coloring matters. With two exceptions, which are resolvable into one, the only preliminary operations to which silken cloth intended to be printed is commonly subjected, are, first, boiling in a solution of soap and carbonate of soda, to remove the *gum;* second, passing through dilute sulphuric acid; and third, washing and drying. Or, CLAUSSEN'S process, given at page 326, may be adopted. The two exceptional cases above referred to, are when the silk is to be printed with a French blue or green; to prepare the goods for these colors, they are immersed during fifteen to twenty minutes in a bath of acetate of alumina at 4° Twaddell, and then dried on a steam-drum to expel the greater part of the acetic acid.

The colors to be printed on silks are always mixed with as little acid as possible, and do not require quite so much thickening as those for wool. No precise rule can be given for the duration of the steaming, which must be regulated according to the quantity of acid in the colors, and other circumstances, but it is considerably less than for woollens. The lantern is well adapted for the steaming of silks.

For the *reds* imprinted on this fabric, cochineal is generally employed; sometimes, however, they are derived from the dye-woods, using oxalate of potassa instead of the oxalic acid which figures in the colors applied to wool, as the silken fibre would inevitably be injured by the free acid. *Blues* for silks are derived either from the carmin of indigo, or from the cyanides, using with the former an aluminous base, and with the latter a base of tin. For *steam-yellows* on silks, the Persian berry is generally employed; but the quercitron yellows are unquestionably more lively and brilliant.

The following may be given as an example of a common *steam-blue* for silk :—In one gallon of boiling water, dissolve three and a quarter pounds of carmin of indigo, seven ounces of alum, one pound of tartaric acid, and thicken with five pounds of gum-Senegal.

For a *poppy-red*, thicken a decoction of two pounds of cochineal in a gallon of water, with one pound of starch; boil, and add, when tepid, two and a half ounces of chloride of tin, and five ounces of binoxalate of potassa in powder; when cold, introduce two and a half ounces of red spirits.

The steam-colors for chalis, or mixed fabrics of wool and silk, are necessarily similar to those applied to silks individually, because, if the acids were present in a free state, and in the same proportion in which they are mixed with wool colors, the texture of the silk in the fabric could not fail to be weakened. When this precaution is taken, the printing of mixed fabrics of silk and wool, both of which are animal fibres, and have nearly the same affinity for the coloring matters, is not attended with the same difficulty as that of delaines, or a mixture of wool and cotton.

Madder Style for Silks.—Though the coloring matter of the common dye-stuffs adheres with too much tenacity to the unmordanted woollen fibre, to render possible the application of the madder style to woollen goods, yet it is sometimes applied to silk stuffs, and was practised extensively for silk handkerchiefs before the introduction of the method of fixing by steam. The general process is the same in its leading features as for cotton goods, but the delicate nature of the fibre, and its strong attraction for coloring matters, render it considerably more difficult.

To illustrate the slight peculiarities of treatment required in applying the madder style to this fabric, a short account may be given of the method of printing a *red and black* design on silk handkerchiefs.

As it is not without much difficulty that the white of the silk can be brought back to its original purity when it has been soiled or discolored by the dyeing operations, great care must be taken, in the first place, to see that stuffs of this description which are intended for printing be perfectly free from every substance susceptible of fixing the coloring matter on parts which are intended to retain their original whiteness, either wholly or in part. There are few printers, therefore, who do not scour and remove the gum for the white grounds on which they intend to operate, by passing them into a bath of soft soap. When the stuff has been thus treated and dried, it is printed first with a mordant for the black design, consisting of iron liquor—acetate or crude pyrolignite of iron—at 10° or 11° Twaddell, thickened with starch. After an ageing of two or three days, the goods are printed with the red liquor for the red design—acetate of alumina, marking 11° Twaddell, and thickened with roasted starch. It is of essential importance to print-on no more mordant than is strictly necessary, for if it be ever so little in excess, it will pass over on the white parts, which will then take on the color strongly. When the printing is finished, the goods are again aged for two or three days, and the next operation is the fixing of the mordants, which, with calicoes, is usually performed with dung or dung substitute, but must be performed in this case by passing the goods through a bran-bath, with or without a certain proportion of sumach. When this substance is added, it is introduced into the clear decoction after the bran has been boiled, and when the bath has fallen to the temperature of 140°. Thirty-five pieces of the silk, divided into five parcels, are passed into this bath, and are left in it for twenty-five to thirty minutes; they are then washed at the wheel. For twenty parcels of seven handkerchief-pieces each, about twenty-six pounds of bran, with three pounds of sumach, are used; the bran decoction is divided into four portions, which are added successively to the bath in proportion as it becomes exhausted.

Perhaps the double arseniate of lime and potassa might be employed with advantage to fix the mordant better, and would only involve the necessity of scouring the goods. After the fixing with bran, the goods are winced in the dye-beck, and the quantity of garancin employed is calculated according to the weight of the raw goods, in the proportion of about an ounce and a half to the handkerchief, or about thirteen or fourteen pounds for one hundred and forty handkerchiefs, the number usually operated upon at one time. To this dye-stuff is added at least double its weight of bran, with a small quantity of vinegar, both to correct the water and to prevent the staining of the white parts. The wincing in the dye-beck is continued for fifty to sixty-five minutes, beginning with a temperature of 120°, and rising progressively to the boiling point. The goods are then cleaned, and submitted to the action of a soap-bath, heated to 160°, to purify as much as possible the unmordanted parts, and to increase the brightness of the colors.

Mandarining Style, for Silks and Chalis.—This most peculiar style, which is so called from certain silk stuffs termed *mandarines*, can only be applied to woollen or silk fabrics, and differs entirely from any of the numerous processes practised with cotton goods. It was much in use for handkerchiefs and other silk goods, before the method of printing with steam-colors was carried to that degree of perfection which it has now attained.

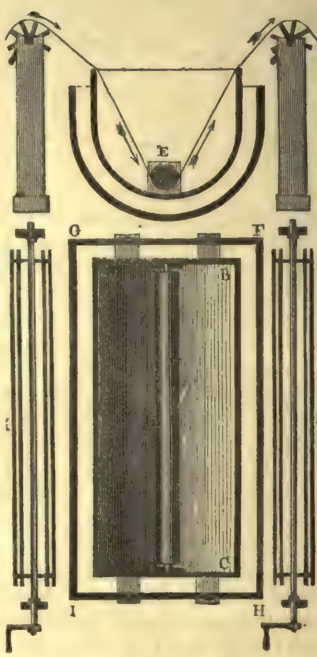
The principle of this curious process is based on the action exerted by nitric acid on colors and on every textile fibre of an animal nature. By exposing a silk or woollen stuff to the action of this acid, more or less diluted, a yellow or orange color, similar to that which it imparts to the skin, is communicated to the cloth, proceeding from a peculiar substance formed through the decomposition by the acid of a portion of the fibre of the cloth itself. The same effect is produced when the cloth has been previously dyed with certain colors, and thus, by printing a resist paste on the parts intended to be reserved, and then passing the goods through the acid, very beautiful and elegant effects are produced, which admit of considerable variety. The mandarining process may therefore be regarded as a kind of combination of the resist and discharge styles.

The operation of the resist in this case is purely mechanical. Its office is simply to preserve the cloth, at those parts on which it is applied, from contact with the nitric acid. Its composition and thorough application to the stuff are, therefore, points of the highest importance, for, should it not act with perfect efficiency, the whole effect would be destroyed. The resist most commonly employed consists of fifteen parts of resin melted into intimate mixture with two parts of suet; or a still better is formed by melting and passing through a strainer a mixture of suet and stearic acid. One or other of these compositions is printed-on with the hand-block; and for this purpose they require to be softened by heat, and kept at a certain uniform temperature, which is accomplished by means of the arrangement represented and described at page 687. The printing-block must also be heated after each impression, by placing it in contact with a part of the apparatus appropriated for that purpose.

As far as possible, the parts on which the resist is printed should form the subject or pattern, and the other parts the ground. If such resists have been printed on a white stuff, which is then passed into nitric acid, the design obtained, on dissolving off the resist, will be a white figure on a yellow ground. These resists may be employed, however, not only to protect certain parts of the stuff from the action of the nitric acid, but also from that of any coloring liquid which is capable of dyeing the stuff at a temperature that will not melt the resist. Very elegant and various effects are produced in this manner. Thus, after printing a part of the design with the resist on a white stuff, the latter may be passed into the blue vat, which will produce a blue ground with a white figure covered over with resist. Allowing this resist to remain on the stuff, and printing the same composition on a part of the blue ground, then passing the goods through the acid, the blue will be discharged from the uncovered parts, and a yellow ground will be obtained, relieved with blue and white figures, the former on the parts covered by the second printing, and the latter on the parts to which the resist was first applied. There is nothing to prevent operating in the same manner on fabrics colored in any other way, or simply mordanted, and afterwards dyed.

The nitric acid to be used in this process is put into a sandstone trough, A B C D—Fig. 409—to the ends of which, A B and C D, boards are fitted on the inside, and holes are made in these boards to receive the journals of the roller, E, which is adjusted lengthwise in the trough about an inch from the bottom. To raise the acid to the proper temperature, this trough is placed in another, F G I H, which may be constructed of wood or copper, and performs the part of a water-bath, the interval between the troughs being heated by steam or otherwise. On each side, and parallel to the axis of the troughs, are two reels, K, L. The goods are coiled upon one of these reels, L, from which they pass into the trough under the roller, E, and then over the other reel, K, as shown in the sectional figure. Motion is given to the reels by the handles, H, I.

Fig. 409.



The acid is diluted with more or less water, according to the kind of effect to be produced. As a general rule, it ought to be used as weak as possible, increasing its power, if necessary, by a higher temperature; but to avoid the risk of melting the resist, the temperature must not be raised beyond 100°. To discharge very strong colors, the nitric acid of commerce is diluted with only half its volume of water. Sometimes this proportion is reversed, but, generally, the water and acid are mixed in about equal proportions. The time of the immersion must vary according to the strength of the acid, the nature of the color to be discharged, and the temperature of the bath. It is for the operator, therefore, to determine the proper time by a preliminary experiment on the small scale. It is never prolonged beyond one minute at most. Instead of a single roller placed at the bottom of the trough, it would probably be better to have two or three, to render more regular throughout the contact of the stuff with the liquid.

After passing through the nitric acid, the goods must be immediately rinsed; and for this purpose another trough or vat, containing a mixture of water and chalk, is placed immediately under the roller, K, or they are made to fall into a stream of cold water. They are then boiled in soap-water, containing a little carbonate of soda, at the rate of two pounds of the former and four ounces of the latter for each piece of thirty yards. In this liquor they are winced for half an hour, which removes the fatty or resinous resist, and communicates an orange tinge to the yellow ground produced by the passage through the acid, or the *mandarining.* They are now rinsed again in cold water, then passed through hot water, rinsed a third time and dried.

Such is a general outline of this peculiar process, which admits, however, of considerable variety in the modes of its application, and is indeed one of the most striking illustrations of chemical ingenuity in the arts, as a few examples will show.

In the first place, a white figure is obtained on an orange ground, by simply printing the resist on the white stuff and mandarining.

In the second place, a figure in red, rose, blue, green, or any color, in short, capable of undergoing the boiling with soap and carbonate of soda, may be obtained on an orange ground, by first of all dyeing the whole piece of the color required for the figures, then printing-on the resist, and mandarining.

Thirdly, when the color desired for the figure is too delicate to stand the action of the boiling in soap, the difficulty is overcome by first padding the goods with a mordant, and after having fixed this in the usual manner, printing-on the resist. The goods are then passed through the nitric acid, to which a certain proportion of tartaric acid has been added, to assist in dissolving off the mordant from the parts which are not protected by the resist paste. This operation is followed by a rinsing and cleansing with soap, when it only remains to dye the goods in a bath of the required color, and those parts alone on which the mordant has been reserved will take the dye.

In the fourth place, a combination of white and blue figures on an orange ground may be obtained in the manner already described.

Fifthly, a white figure on a dark green ground is obtained by first printing-on the resist; then mandarining; then dyeing in the indigo-vat to produce a green by the combination of the blue with the mandarine yellow; lastly, boiling with soap and alkali to impart to the yellow of the green the orange tinge, by which it is darkened to the desired shade.

In the sixth place, for white, blue, and orange on a dark green ground:—

1. Print on the resist for the white;
2. Dye light blue, wash, and dry;
3. Print on the resist for the blue;
4. Mandarine, wash, and dry;
5. Print on the resist for the orange;
6. Dye dark blue to produce with the orange a dark green ground;
7. Clean and dry.

Lastly, it may be observed that instead of using nitric acid *per se*, this acid may be associated with iron salts or other saline solutions capable of combining with the stuff, and in this manner a variety of figures will be obtained on a bronze or other ground. Thus, for the bronze or solitaire style by this process, the mandarining mixture is one gallon of nitric acid of specific gravity 1·17, mixed with three pints of solution of nitrate of iron of 1·65 specific gravity; or a darker tint may be obtained by increasing the quantity of nitrate of iron.

THEORY OF THE FIXATION OF COLORING MATTERS IN DYEING AND PRINTING.—There are two methods of coloring stuffs which must not be confounded with each other. By one of these, as in the case of the oil-painter, the coloring matters, lakes, *et cetera*, are mixed with gums or varnishes to make them into a color which is applied to the stuff, and which, on drying, adheres to it. Whether these coloring matters are mixed with a fat varnish, drying oil, gluten, white of egg, starch, or mucilages, the result is always the same; but this operation, which is purely mechanical, and which may be performed on every kind of fabric, will only occupy the printer's attention so far as relates to the discovering of that glutinous body which is most capable of rendering this or that colored substance adherent to such or such fabric. By the other method, the coloring matters, brought to the proper conditions, are deposited and then fixed on the goods in such a manner as to be incorporated with the fibre, and only to be capable of being detached from it by the intervention of a more or less powerful chemical agent; but some of them—and in this number are several substances of the organic kingdom, such as indigotin, carthamin, curcumin, and among the mineral colors, the oxides of iron, chromium, lead, *et cetera*—only require to be applied on the goods; whilst a greater number of others, such as madder, cochineal, Brazil and Campeachy woods, quercitron, and weld, unite with the different fibres only by the co-application of auxiliaries, which are designated by the name of *mordants;* it is in consequence of this difference that all who have written on dyeing have divided coloring matters into *those which adhere to the goods of themselves*, and *those which can only be fixed by the co-application of mordants.*

To discover the cause in virtue of which the different colored bodies unite with the textile fibres of cotton, wool, and silk, to such a degree as to form with them one body; to explain how it happens that one and the same substance has not the same aptitude for each of these fibres—such is the question which first presented itself to the scientific men who devoted their attention to the application of colors, and the solution of which is more especially important to the art of dyeing, of which the *printing* of fabrics is but a particular case. HELLOT and LE PILEUR D'APLIGNY, MACQUER, BERTHOLLET, BERGMANN, and CHEVREUL, who are justly entitled to rank as high authorities on this subject, have given forth different opinions on this point. The first two saw in the fixation of the colors on the goods only a purely mechanical operation; the last four, on the contrary, only an operation purely chemical.

Opinions so opposite, and sustained moreover by such high authorities, demand, for these reasons alone, a searching inquiry into the truth; but a new motive to this inquiry is found in the views and arguments published by one of the most distinguished scientific printers in Great Britain, Mr. WALTER CRUM of Glasgow, who, in a recent paper, tends to revive the opinion of HELLOT and LE PILEUR D'APLIGNY.

To explain the difference between fast and fugitive colors, **Hellot** attributed to the fibre of wool in particular, pores susceptible of opening and closing, in which the coloring particles lodge. When fixed or glued there by the astringent substance which is commonly made to intervene in the operations of dyeing, and which, according to him, would form a coating, the color is *fast;* in the contrary case, it is *fugitive* or *fading*. Hence he affirmed that what he termed the *invisible mechanics* of dyeing consist in dilating the pores of the body to be dyed, to deposit therein the particles of a foreign substance, and to retain them by a kind of coating, which neither rain-water nor the rays of the sun can injure; to choose the coloring particles of such tenuity that they may be retained sufficiently encased in the pores of the stuff, opened by the heat of boiling water, then shut again when cold, and further coated with the kind of cement which is left in these same pores by the salts chosen to prepare them. Whence it would follow, that the pores of the fibres of woollen stuffs should be cleaned, enlarged, coated, then closed, that the coloring atom may be retained, not unlike a diamond in the bezel of a ring. He affirmed that there are no coloring ingredients of the class termed *fast* which have not, more or less largely developed, an astringent and precipitating property; that this suffices to separate the alumina—one of the salts which are employed in the preparation of the wool before dyeing it: that this earth, united with the coloring atoms, forms a kind of lake similar to that of painters, but infinitely finer; that in the bright colors, such as scarlet, for which alum cannot be used, it is necessary to substitute for the earth of that salt, which is always white when the alum is well selected, another body which may furnish to these coloring matters a base also white; that pure tin affords this base in the dyeing of scarlet; that when all these minute particles of earthy lake are introduced into the dilated pores of the article, the coating which the tartar—another salt employed for its preparation—has left therein, serves to cement these atoms in the pores; and that, lastly, the closing of the pores by the cold serves to retain them there.

Consistently with these ideas, **Hellot** suggested that perhaps the colors called fugitive are only so because the material to be operated upon is not sufficiently prepared; so that the coloring particles being only deposited on the smooth surface, or in the pores, the capacity of which is not sufficient to receive them, it is impossible that they can resist the least washing. If means were discovered of giving to the coloring parts of the dyewoods the astringency which they want, and at the same time the wool were prepared to receive them, as it is prepared, for example, to receive madder-red, he conceived that one might succeed in rendering these woods as useful to the dyers of fast colors, as they have hitherto been to the dyers of fugitive colors.

Le Pileur d'Apligny lent the support of his talents and of his pen to the theory of **Hellot**; but instead of confining himself, like the latter, to study only wool in its relations with coloring matters, he regarded, under the same view, silk, cotton, hemp, and flax; and to render this theory more probable, he was careful to precede it by considerations on the texture of the different fibres. Wool, according to him, is composed of an infinite number of filaments, of the nature of hairs, and containing like them a marrow or fatty substance, being nothing but pipes perforated in their whole length, and laterally, with an infinitude of orifices, by which the foreign substances reach the heart of these tubes previously deprived of their marrow; and this fibre being, of all the textile fibres, the most porous, is from that very circumstance the easiest to dye, and is at the same time that which absorbs the most coloring matter Silk is only a series of molecules of dried animal jelly, which, shrinking more or less by its desiccation, and thus giving rise to inequalities, producing pores which exist only at the surface of the thread, admit only colors extremely dilute and in very small quantity, which explains, according to him, why silk is one of the most difficult fibres to dye. The staple of cotton, being much finer than that of wool, but hollow like it, filled with marrow and furnished with lateral apertures, is also more difficult to dye, because it admits into its pores and interior only colors much more attenuated and in less proportion. The threads of flax and of hemp, being finer still than the preceding, are equally porous. From these considerations, **d'Apligny** arrived at the conclusion, that without gratuitously assuming the existence of any chemical affinity between the colored infusions and the goods to be dyed, one can easily understand why that which communicates to wool a scarlet color, does not give the same hue to silk, and imparts no color to cotton. On this theory, it gives to silk only a very dirty color of port-wine lies, because the particles of cochineal form a lake with the oxide of tin diffused in the dye-vat, which lake the pores of the wool are sufficiently large to lodge, but those of the silk, being too small, cannot admit it—they admit only the cadaverous parts of the cochineal more minute than those of the lake, because they are simple—but almost all the color of which has been absorbed by the oxide of tin. Cotton, in its natural state, admits none of it into its pores; but, for the same reason, it receives, like silk, a brownish-red color when it has been properly deprived of its gum. On this principle, it further results from the different texture of the substances to be dyed, that each of them takes different shades in the dyes which can penetrate their pores, though the same processes are employed to dye them. **D'Apligny** adds that this observation holds good even in regard to stuffs differently woven, although of the same material; as the different modes of manufacture produce in a greater or less degree a closing of the pores of the stuffs, which makes them receive more or less of the colored particles. It is this closing, he says, which produces the effect that a cutting of scarlet cloth is white in the interior, the colored molecules being too coarse to penetrate into it, which does not happen with other dyes, for which the goods are alumed before dyeing.

These views, as **d'Apligny** himself states in his preface, are only a development of the ideas of **Hellot** on the dyeing of woollens.

Dufay, in 1737, and **Bergmann**, in 1776, were the first to put forth a different opinion on this subject, and to recur to chemical affinities to explain the property possessed by a coloring matter of uniting with this or that stuff in preference to another. **BERGMANN** especially, in his work on Indigo, expresses himself clearly on this subject, by saying that, if the sulphate of indigo is attracted by preference, and in greater proportion by wool than by silk, the cause of this must be found in the difference of affinity which exists between these two fibres; one of which, that of the wool, is sufficiently powerful to take from the dye-bath all its coloring particles, whilst the other, that of the silk, being much weaker, can only diminish the proportion of the colored molecules which exist in such a bath.

MACQUER, to whom the art of dyeing owes the most important works which have been written on the means of fixing colors, seemed, at least at one period of his life, to lean to the ideas of **HELLOT**; but in 1778, in the article DYEING of his *Dictionnaire de Chimie*, he gives forth clearly a quite different opinion; for after reciting some peculiarities essentially distinctive to the coloring matters which produce hues as varied in their shades as in their intensity, by varying the fibre on which they are impressed, this skilful chemist adds:—The most general conclusion which appears to result from these particular details, is, that wool and all animal matters are, of all substances that admit of being dyed, those which lend themselves most readily to the action of the dye; that linen and all matters purely vegetal are, on the contrary, those which it is most difficult to dye, which take the least number of colors, and further, which take them on less fine and less firm; lastly, that silk and other substances which would appear to hold a middle place between matters purely animal and those that are purely vegetal, hold also the middle place in this respect in dyeing operations. He does not deny that this greater or less facility of taking and retaining the dye, possessed by different substances, depends in great part on the number, size, and arrangement of the pores, and on their proportion to the colored particles of the dyeing substances; but this, he conceives, is not the only cause of the great differences which one observes in the relative nature of the substances to be dyed; and he urges the following fact, which is very constant and well known in dyeing, as affording satisfactory evidence of the truth of this:—

If, after aluming as much as possible a pound of wool and a pound of silk, each of them is afterwards dyed separately in a cochineal bath, they will both take a very beautiful and very fast crimson; but with an equal quantity of cochineal in each bath, the color of the wool will be infinitely fuller and more intense than that of the silk: this difference is so great, that one can succeed in giving to the crimson of the silk as much intensity as to that of the wool, only by employing more than double the quantity of cochineal; that is to say, it requires two and a half ounces of this ingredient to give to the pound of silk as full a crimson as that which the pound of wool takes with a single ounce of the same substance. And it is impossible to say, with **D'APLIGNY**, that this arises from the pores of the silk being much finer than those of the wool, so that it can only take the finest coloring parts of the cochineal, whilst the wool takes them all, because its pores are larger or more numerous; for if this were the case, there ought to remain much color in the bath after the silk has absorbed all that it can, and refuses to take on more: now, this, as **MACQUER** justly remarks, is not what happens; it is always the case, on the contrary, that the silk, which has been dyed with two and a half ounces of cochineal per pound, leaves its bath as clear, and as much exhausted of color, as that of the wool which has been dyed with a single ounce of cochineal.

There must, therefore, be some other cause than the size and arrangement of the pores, which exerts a powerful influence in the difference of the effects that are observed in relation to the nature of the substances which receive the dye. The pores, by multiplying the surfaces and points of contact of the material to be dyed with the tinctorial substance, cannot fail, says this distinguished chemist, to facilitate considerably the application of the latter; but it is not a simple encasing of the colored atoms in the pores, which serve as a bezel to them: there is further, he says, a real adherence of contact, and even a chemical combination of these colored particles with the substance itself on which they are applied; and this adherence is, as in all other combinations, more or less intimate and powerful, according to the nature of the substances which unite together. It is easy to conceive, in fact, that the number and depth of the pores, far from increasing the effect of the coloring particles, is rather calculated to absorb them, to conceal them, and consequently to diminish the intensity of the dye. It is, therefore, chiefly, by being applied on the surfaces, where nothing covers them, that the colored atoms of the dye-stuffs communicate their color to the dyed goods; it is a kind of painting in which the colors are applied, and adhere to the surfaces by the effect of contact, and in virtue of the greater or less affinity which they have with the particles of these same surfaces, according to their respective nature.

In treating the same subject, **BERTHOLLET** has introduced into the question no new argument; but, in his Elements of the Art of Dyeing, he groups all the important facts of this art, and draws from them a series of conclusions, all of which tend to induce the opinion that the phenomena presented by it are dependent on chemical affinity.

Of all chemists, M. **CHEVREUL** is the one who has searched most deeply into this important matter; and in comparing the general phenomena of dyeing with those which natural philosophers and chemists generally consider as dependent on molecular forces, the causes of chemical action, he arrives at the conclusion, that the first are of the number of those which take place when two or more bodies are in contact, and their combination is effected slowly.

It appears, therefore, that, whilst **HELLOT** and **LE PILEUR D'APLIGNY** attribute all the effects produced by coloring matters in the operation of dyeing, to the existence in the fibres of pores or cavities, more or less numerous and spacious, in which the coloring atoms lodge, all the other chemists repudiate this view of the subject, and trace the same effects to chemical affinity.

Nevertheless, the conclusions of MACQUER have a peculiar character, requiring special consideration; while rejecting the opinions put forth by LE PILEUR D'APLIGNY, he does not deny the influence of the pores, and of the nature of the fibres, and lays down the formal proposition, *that the coloring parts apply themselves and adhere to the surfaces of the fibres, by the effect of contact, and in virtue of the greater or less affinity which they have with the parts of these surfaces themselves, according to their respective nature.*

Such were the notions entertained by scientific men on the causes of the adherence of coloring matters to the goods, when the views of Mr. WALTER CRUM were published. According to the experiments of DE SAUSSURE, experiments so full of interest and so well known, chemists were aware that charcoal absorbs gases without altering their nature, in proportions which vary, according to the nature of these gases, its own nature, and its state of porosity. No one is now ignorant of the applications which are daily made of this body in the arts, for decoloring sirups, by freeing them from different substances. It is in connection with this order of facts, and enlightened, moreover, by the theoretic works of the celebrated chemist of Berlin, that Mr. CRUM proceeds to adduce arguments in favor of the ideas of HELLOT. He advances, in fact, after passing in review the different modes of action of porous bodies, that several dyeing operations depend on the capillary action described by DE SAUSSURE; and this opinion he bases chiefly on the result of the microscopic examination of the fibres of cotton which was made by Mr. THOMPSON of Clitheroe, and M. BAUER—this examination having established, that these fibres are formed of transparent and glass-like tubes, which, though cylindrical before their maturity, flatten on the contrary from end to end as they ripen, and then present the aspect of two separate tubes. Mr. CRUM thinks that, since the sides of these tubes permit water to pass through, they must be porous; but he adds, that neither the form, nor even the existence of such lateral perforations have been capable of being discovered by the aid of the most powerful microscope. This, as will be seen, is the hypothesis put forward by LE PILEUR D'APLIGNY, presented under a new form, and with the reserve of a mind essentially experimental. This being assumed, the eminent Scottish manufacturer explains the fixation of the colors in the following manner. He first admits that the mineral base of a madder-dyed color—oxide of iron or aluminum—treated with a volatile acid—*acetic acid*, for example—gives rise to a solution which, when impressed on the fabric, is there gradually decomposed in course of time, abandoning its acid, *just as it would be decomposed in similar circumstances without the intervention of the cotton;* and if this base, deposited on the fabric, remains adhering to it so powerfully as to resist the action of the most perfect washing, it is because the solution, after having penetrated by the lateral openings into the interior of the tubes which compose the cotton, is there decomposed, and the oxide being set free in the narrow passage where it is enclosed, can no longer be disengaged from it. When the cotton, then, composed of *sacs* thus lined with metallic oxide, passes into a madder-bath, or one of any other coloring matter, the latter combines with the metallic oxide by a true chemical action to form a lake, or what is properly called a color.

Such is the theory adopted by Mr. CRUM, and which he endeavors to justify by several arguments. According to his view, for example, by making the adherence of the colors depend on the force of attraction, which unites the bodies atom to atom, one is compelled to admit the disorganization of the fabric, even though experiment proves that cotton wool can be dyed by metallic oxides without its fibre being injured, since it is recovered with all its properties entire, when, by chemical processes, it is deprived of the color with which it has been impregnated. Mr. CRUM imagines that he finds a new proof in support of his view of the subject, in the observations he has made, both by the naked eye and with the aid of the microscope, on the staples of cotton dyed blue, red, and yellow; and whence it would result, that those hues which appear uniformly diffused over the whole surface of the fibres, appeared only, when observed with the microscope, to color the internal side of the tubes, which would be themselves colorless. The coloration of plants offers to him also a subject of comparison, with which he connects the phenomena of dyeing, and, with Dr. LINDLEY, he regards their cellular tissue as formed of small vesicles, the openings of which, though not visible, *must nevertheless exist,* since they are permeable to liquids, and being filled with different tinctorial matters, give rise to the colors which characterize the different organs of plants. Lastly, Mr. CRUM discusses the operations of indigo-dyeing, with the view of proving that there is no chemical combination, in the proper sense of the word, when the coloring matter is fixed on the goods.

Such are, in few words, the principal considerations which this chemist brings to bear on the question. PERSOZ holds a different opinion, and proceeds to examine how far this theory, which, by the author's admission, has several points of resemblance to that of HELLOT and LE PILEUR D'APLIGNY, admits of being supported by the facts on which it is based. The following are PERSOZ'S views on the subject:—

According to the first proposition, the acetate of alumina, for example, would be decomposed in presence of the goods, just as if it were free, and experience seems to him to be here opposed to such an assertion. He does not dispute that this salt, free, or in presence of the goods, is composed of acetic acid and alumina, or basic acetate; but that, for equal quantities, and diffused over equal surfaces of cotton cloth, plates of glass, mica, or platinum, and dried, moreover, in the same conditions, this acetate gives up always the same quantity of alumina, is what he finds it impossible to admit. In fact, if the desiccation takes place at a temperature but little elevated, the quantity of the earth, taken from the acetate by the cotton, will be incomparably greater than that which would be liberated on the glass or mica plates; it must be concluded, therefore, that the textile fibre of the cotton exercises a powerful influence on the decomposition of the acetate of alumina. But if any doubts still exist as to the part which the fibre performs in the decomposition of a mordant, the subjoined fact ought, he thinks, to dispel them. A solution of cubical alum, submitted to spontaneous evaporation, yields crystals of *cubical alum;* but if one puts in it, for a certain time, stuffs of silk and cotton, this same solution now furnishes, after undergoing a spontaneous evaporation, nothing but octahedral crystals of alum, deprived as it is by these stuffs of a notable portion of its base.

If from this proposition one passes to that which is, as it were, the foundation of Mr. CRUM'S theory, and according to which the cotton fibre must be regarded as formed of small sacs, capable of being filled with coloring matter, or with an oxide susceptible of afterwards uniting chemically with the dyeing substance of a dye-vat, this will be found not less opposed to all the data of experience. How explain, in fact, that liquids so viscous as the colors thickened with gum or starch, which are printed on fabrics, can drive out the air which exists in the sacs of the cotton fibre, and occupy its place? Must it be assumed that the sacs contain no air, or that they are endued with a very powerful capillary attraction? This view of the subject appears scarcely admissible; nevertheless, it is not the greatest difficulty which this hypothesis presents. The dyer prepares with starch, and with a certain quantity of sulphate of copper, the goods which are to be dyed in the blue-vat, in order to economize the coloring matter of the indigo. According to Mr. CRUM'S theory, this preparation, filling the small sacs, ought to be an obstacle to the dyeing, and yet experience proves, on the contrary, that it favors it. In the same manner, in dyeing Turkey-red, it has been seen that the goods are first impregnated with oily preparations, and afterwards with astringent substances, such as nutgall, sumach, *et cetera*, before interposing the aluminous salt, which serves for a base in this kind of dyeing.

When a cotton fabric is dipped in a chloride solution, or one of sulphate of manganese, and afterwards passed into an alkaline menstruum, oxide of manganese is precipitated, which, according to Mr. CRUM, is rendered insoluble, not at the surface of the fibre, but in the heart of the sacs, where it absorbs a fresh quantity of oxygen, and is transformed into binoxide of manganese, which thus adheres to the fibre; but a fabric, which, by this process, would be charged to the utmost with binoxide of manganese, should no longer be able to attract to it another coloring matter; and, nevertheless, it is so well established that, in such case, it is more than ever fitted for being impregnated with indigo-blue, that advantage is taken of the property possessed by the higher oxides of manganese, to favor the precipitation of this blue, for obtaining double shades by it. It will not be alleged that the indigo adheres only to the oxide of manganese, and that it is sufficient to withdraw this oxide, to cause at the same time the disappearance of the coloring matter which is associated with it, since it is at any time possible, by destroying the binoxide of manganese by means of chloride of tin, to cause the reappearance of the blue with the same brightness and firmness it possesses when it is fixed directly on the goods without the co-operation of this oxide.

Deposited on the surface of a cotton fabric, the sulphate of lead, which is insoluble, is removed by the slightest affusion with water; but, by simply dipping the goods in a milk of lime, one can render it adherent to the fibre without making it pass into the liquid state, and, consequently, without its being capable of penetrating into the vesicles of the fabric.

Lastly, many colors that have little adherence to the goods, even with the co-application of certain mordants, are strongly fixed upon them when the goods are previously prepared with oxide of tin. This oxide, in the same way as the fatty bodies and astringents employed in the dyeing of Turkey-red, should, if the hypothesis now engaging attention be well founded, fill the cavities of the cotton fibre, and so far oppose the introduction and fixation of the colors which are subsequently applied to it.

Passing from this order of facts to another, it is easily seen, on examining attentively a dyed or printed stuff, that the color upon it is always at the surface, and in relief—a fact which nothing can prove better than the facility with which this color is taken off by thickened corrosives. If it adhered to the fabric only by penetrating and filling the vesicles of the fibres, how would a thickened acid be capable of introducing itself into these same vesicles, and removing the oxide? How would the slightest washing be sufficient to clear these cellules of the chemical compounds which would be formed in their interior? On the other hand, does not the great art of producing a lively and brilliant Turkey-red consist in depositing the mordant or the color only at the surface of the goods? If the centre were impregnated with it, the red would become brown, and would never admit of being brightened.

On the other hand, the fact that the fibre is found intact after the operations of dyeing, whilst it would be disorganized if its combination with the coloring matter were brought about by the union of atom to atom, in virtue of the force of attraction; and also the fact, that indigo unites with the fibre, while retaining all its properties, do not prove that there is no combination between the tinctorial matter and the fabric; the explanation of these apparently abnormal phenomena depends, in PERSOZ'S opinion, entirely on the point of view from which one regards them, and on the distinctions which are established in the phenomena of attraction.

In the existing state of knowledge, the inertia of matter is considered as a general property of bodies, and it is acknowledged, that if their particles are kept in equilibrium in relation to each other, it is by their being submitted to the influence of two opposing forces, which tend the one to draw them together, the other to separate them. The first, the only kind of action which requires attention at present, is designated by the name of *attraction*; but as it acts sometimes on masses which are placed at great distances from each other, at others on particles which are in immediate contact, it has, whether rightly or wrongly, been distinguished into *planetary* attraction and *molecular* attraction; further, as this last is manifested, either on particles of the same nature, which are thus attracted towards each other so as to form an aggregate of homogeneous particles, or on particles of a heterogeneous nature, to create a *whole* different and distinct from the composing atoms, the molecular attraction has been further divided into *cohesion*, or a force tending to unite molecules of the same nature, and *affinity*, or that force which tends to unite molecules of different nature, or to bring about what chemists term *combination*. These distinctions will sooner or later disappear, for they are less to be regarded as truths than as the necessary results of the wants of a particular period. What characterizes, in fact, the first phase of the development of a science, is always a tendency to differentiate and group the phenomena which it presents; but as the science becomes more advanced, there is soon produced a reaction, the contrary tendencies of which have no other end than the assimilation and binding together of all the elements of which it consists.

As it is attraction which animates the material particles, it must be recognised as the cause of the movement of matter, and accepted, without wishing to ascend higher, as an essential property of bodies, which can no more be explained than *extent* and *impenetrability*.

These preliminaries being laid down, and regarding as identical the phenomena of cohesion and affinity which appear to him the effects of one and the same cause, PERSOZ thinks it may be proved that the fixation of the colors on stuffs is only due to attraction. To arrive at this demonstration, he lays down, in the first place, some general considerations on the fixation of coloring matters; then passes in review the principal phenomena of attraction, with the double object of bringing out the differences which they may present, and discovering those which exhibit the greatest analogy with the fixation of this or that color.

The organic and the inorganic kingdoms, especially the former, furnish a great number of substances which possess the property of dyeing stuffs, either constituting colors by themselves, or entering as elements into coloring compounds of a more complicated nature; but, to receive an application, these substances, simple or complex, must unite, if not by themselves, at least by the intervention of a suitably selected body, two essential qualities: first, *that of being insoluble or nearly so;* second, *that of resisting as much as possible the destructive action of the air and the solar rays.* The first of these qualities is indispensable; for if it be wanting, there is *coloration* of the goods, but not *dyeing*, in the proper sense of the word: a simple washing with water suffices to discharge the color. The second is not essential in the same degree, since it is subordinate to the stability which is intended to be given to the colors applied to a fabric.

Indigotin, carthamin, curcumin, oxide of iron, oxide of chromium, sulphide of arsenic, sulphide of antimony, are dyeing substances by themselves. When one interrogates experiment as to the means of making them adhere to the goods, so strongly as to constitute one body with them, it is found to be necessary either to form these colors on the stuff itself, by putting in presence of the latter the elements of which they consist, and one of which at least must be soluble, or, if these tints are previously formed, to make them enter into a soluble combination with which one impregnates the fabric to set them afterwards at liberty, in such a manner that they may be in immediate contact with it at the moment when they pass from the soluble state in which they existed in their combination, to the state of insolubility which belongs to them in their isolation. It is thus that the blue color of indigo fixes itself on the goods only so far as they are saturated with reduced indigo, and afterwards exposed to the action of the air, which, by its oxygen, transforms the indigo-white into indigo-blue; that the rust color of sesquioxide of iron is stable only to that extent in which it is deposited on the fabric in the nascent state, either as protoxide, which, by oxidizing in the air, passes by degrees into the state of sesquioxide, or in the state of sesquioxide at first. The color of sesquioxide of chromium is fixed only in the same conditions. Again, to make the sulphides of antimony and arsenic adhere, it is sufficient to apply to the goods one of the saline and soluble combinations of these bodies, then to decompose it by an acid so as to set them at liberty. The fixation of carthamin takes place under circumstances nearly similar.

The greater part of coloring matters—nine-tenths at least—are not of a dyeing power by themselves, and only become so by entering into a combination which has for its object, not only to give them the first quality essential to every tint for being fixed, *insolubility*, but oftener also to make them contract a shade which they do not assume by themselves. The coloring matter of madder, for example, which is soluble in water, acquires the property of dyeing only in so far as it is combined with a body capable, in the first place, of forming with it an insoluble compound, as certain fatty substances, the oxides of aluminum, tin, iron, *et cetera*, and then making it contract the hue which one desires to obtain.

The different dye-woods do not dye better by themselves than madder: and they require, like it, to enter previously into a combination.

Chromic acid itself, rich as it is in color, becomes a dyeing substance only so far as it forms part of a saline combination, which should present, along with the shade desired, the greatest possible insolubility. Even the alumina, which serves for a base to all the organic colors, is not capable of fixing the chromic acid.

It is only in so far as they are formed on the stuffs themselves, that the dyeing compounds of this group become adherent to them. In any other case there is no dyeing, unless, as sometimes happens, the combination becomes by slow degrees insoluble, either by itself —*carthamin*—or by the intervention of a suitable agent—*catechu*. Experience proves, moreover, that of the two substances which usually concur or co-operate to the formation of the color, it is that which is insoluble which should be fixed first on the fabric, and with the same precautions as if one were dealing with one of the substances which are of a dyeing nature when used by themselves. The dyer deviates from this rule, only in so far as the elements of the lake, happening to be equally soluble, and endued moreover with an equal inclination for the fibre of the stuff, render it a matter of indifference whether the latter be first impregnated with the one or the other: thus the colored combination which is formed by nut-gall and a ferruginous preparation, is rendered adherent either by first depositing the iron compound on the fabric, and afterwards passing the latter into a decoction of nut-gall, or by commencing with impregnating the stuff with this infusion, to pass it afterwards into a ferruginous preparation.

This rapid glance at the formation and fixation of dyeing substances, will doubtless suffice to make it understood that the subject under consideration presents different orders of facts, which it is necessary not to confound. In the fixation of indigo, for example, there are, on the one hand, the formation of indigo-blue, and on the other, the adherence of the latter to the stuff. The first of these facts enters into the phenomena of oxidation that are best defined; the second into those of adherence or juxtaposition, which are confounded more or less with the facts pertaining to the aggregation of similar particles. In the fixation of the color of madder, and of all its congeners, there are in like manner two orders of facts: the one which relates to the most clearly understood chemical actions—namely, the union of this coloring matter with the oxide, which is called in to give it, besides the insolubility necessary to it, the desired shade; the other, which consists in the juxtaposition and adherence to the stuff, of the lakes which it produces. So, in the fixation of chromic acid, considered as a coloring matter, it is necessary to distinguish between the formation of the colored saline compound which one wishes to obtain, and its fixation, properly speaking, on the fabric. There are, therefore, in all the operations of dyeing and of the fixation of the colors, certain phenomena, which, inasmuch as they belong to the most common chemical reactions, cannot give rise to any discussion; let it now be considered whether it be not possible to dissipate likewise all uncertainty in what concerns the others.

Always when two bodies are brought into contact in suitable conditions to react upon one another, their molecules, by combining, or being in juxtaposition, form a compound which differs in its properties from those of the component substances, by so much the more as the physical properties of these last exhibit a greater difference from each other. Thus, in the oxides, as in the greater part of the metallic sulphides, the properties of the metals have almost completely disappeared, whilst in the combinations of the metals which present less dissimilitude among themselves, the properties of the compounds approximate more to those of the components. It is more especially in the saline combinations of a high order that the justness of this remark is evidenced.

In running over the scale of chemical affinities, from one of its extremities, where two bodies, endued with opposite properties, combine to form a whole, which, most generally, has no longer any apparent resemblance to its components, to the other end of the scale, at which bodies unite without their union giving rise to physical phenomena that are apparent, or that manifest any notable changes, one remarks that, in general, the compounds which differ most in volume from that of the mean of the components, are those in which the greatest differences are shown; and further, that the combinations which, in taking place, develop the most heat, are those in which the properties of the compounds exhibit the greatest divergence from those of the component materials.

Along with these phenomena, in which two simple or compound bodies are attracted to one another to form a new whole, having more or less resemblance to the components, there are others which, in appearance, seem to be different from the former, but which, in reality, belong to the same order, as the reader will be able to judge.

It is known that two very flat smooth plates laid one over the other, without the interposition of air, adhere together; and by an experiment of M. CLEMENT DESORMES, two plates of glass thus placed on each other were found to unite or solder together so strongly as to form as it were but one piece. It requires, therefore, only *juxtaposition* to determine a species of attraction; and hence it may be conceived that the molecules of a saline solution, whether of the same or of a different nature, but physically comparable both in regard to their dimensions and their geometrical form, may give rise to an aggregate, reproducing on a large scale the figure which they have in that state of extreme division in which they are not visible: it is seen also, that the particles of a salt held in solution pass to the solid state by assuming a definite form, which is the same whatever be the size of the crystals. In like manner, when, by a sharp stroke, one causes the disaggregation of a crystal of Iceland spar, it is found that the pieces into which it is divided are a faithful image of the mass. On calculating the volumes of the equivalents of the sulphates of zinc, magnesia, and iron, one finds that they are the same, and may be represented by 896 cubic centimetres; it is not surprising, therefore, that these salts crystallize together, and in every proportion; and as they affect the same crystalline form, and the dimensions of their molecules are the same, it hence results as a consequence that, in a given condition, they may concur in the formation of an aggregate which will contain without distinction predominant quantities of one or the other of these salts. The volume of one equivalent of octahedral alum is 3584 cubic centimetres; that of chrome alum, isomorphous with the former, is 3584 cubic centimetres; a crystal of ordinary alum may, therefore, be developed in a solution of chrome-alum, without changing its form, and reciprocally.

The difference which exists between these two orders of phenomena is, that in the latter the juxtaposition is immediate, so that particles of the same or a different nature, but identical in form and dimensions, being in contact, place themselves close to each other, whilst in the former this juxtaposition has not the same character, being subordinate to the changes which supervene in the dimensions of the particles of the heterogeneous bodies which are present. Whence it must be concluded, as regarding this latter order of facts, that to find the conditions in which two bodies combine, is to establish the condition in which their molecules are brought to the dimensions which render their juxtaposition possible, whether it be that one of them, by giving up the whole or part of the caloric which holds its particles at a distance, is brought to the dimensions of that in the presence of which it is, or, on the contrary, that by absorption of caloric, the particles of this body acquire the volume which they must occupy in the combination.

Lastly, there is a third order of phenomena which are more difficult to reconcile than the former two: those, namely, which are especially exhibited by porous bodies, or bodies reduced to powder.

The writings of MOROZZO, ROUPPE, NOORDEN, and especially those of THEODORE DE SAUSSURE, have made known, with reference to this subject, facts of the greatest importance, by showing the property possessed by all porous bodies, and charcoal in particular, of absorbing gases—an absorption which depends:—

1st. *On the degree of heat at which it is conducted*, since the absorption is greater in proportion as the temperature is lower.

2nd. *On their pressure*, the absorption being greater in proportion as the pressure is higher.

3rd. *On the nature of the gas*, since equal volumes of a charcoal of the same nature absorb the following proportions of the different gases enumerated: namely,

90	times their	volume of	ammoniacal gas.
85	,,	,,	hydrochloric.
65	,,	,,	sulphurous acid.
55	,,	,,	sulphide of hydrogen.
40	,,	,,	nitrous oxide.
35	,,	,,	carbonic acid.
35	,,	,,	bicarbide of hydrogen.
9·42	,,	,,	carbonic oxide.
9·25	,,	,,	oxygen.
7·5	,,	,,	nitrogen.
1·75	,,	,,	hydrogen.

4th. *On the nature of the absorbing bodies*, since, as DE SAUSSURE has remarked, meerschaum absorbs more nitrogen than hydrogen, and, on the contrary, the different woods condense more hydrogen than nitrogen; and of all the bodies on which this chemist operated, silk, wool, flax, tin, the wood of hazel, mulberry and willow, pyrophorus, metallic powders, plasters, spongy carbonate of lime, Vauvert quartz, hydrophany, asbestos, brittle schist, meerschaum, and the charcoal of boxwood—of all these substances the last exhibited the greatest absorbing power.

5th. *On the number of the pores*, for if two equal weights of the same charcoal, one of which has been finely pulverized, are put in contact with the same gas, the charcoal not pulverized absorbs 7·25 times its volume, and the other only 4·25.

6th. *On the diameter of the pores*, for, according to DE SAUSSURE, the charcoal of cork, the density of which is 0·1, does not sensibly absorb air, while that of willow, having a gravity 0·4, absorbs four and a half times its volume, and that of wood with a density of 0·6, seven and a half times its volume.

7th. Lastly, *on the emptiness or vacuity of the pores*, which makes the absorption the greater in proportion as it is more complete.

The gases fixed in this manner are absorbed in their entirety, without undergoing decomposition; for the slightest elevation of temperature, or a diminution of pressure, is sufficient to set them at liberty, retaining all their properties. Oxygen and nitrous oxide are the only gases which, when absorbed by charcoal, are no longer given out in a complete form, seeing that in these circumstances they enter into combinations with that body.

The action of porous bodies is so powerful, that DOBEREINER, DULONG, and THENARD, and many others after them, have turned this property to account to realise chemical combinations in conditions of temperature in which it was far from being supposed that such were possible. How does it happen that in these experiments the effect of a porous body is equal in power to that which would only be obtained by a pressure of several atmospheres, or by a considerable depression of temperature, if the liquefaction of the gases were attempted directly?

The effect which solid and porous bodies produce on the gases is equally realised by liquids which, as is well known, dissolve them. It has even been observed in connection with this subject, that the absorption of gases by porous bodies is in proportion to their solubility in water, since, as far as can be ascertained, those which dissolve most easily in water are also those which are absorbed in the greatest quantity.

With this same class of phenomena are connected another series of facts not less surprising, but less clearly established: animal charcoal, brought into contact with solutions of coloring matter, renders them colorless, and this property is common to it with many other bodies, such as metallic oxides and basic salts. But the question arises, are the reactions of these different bodies on the colored solutions due to the same cause? Does the charcoal act in the same conditions as the metallic oxides and the basic salts? Evidently not; for it is because these last intervene as elements generating the salts, that they fix quantities of coloring matters proportional to their respective equivalents; and besides, the coloring matter is only separated from them by the intervention of a body which performs the same chemical part, but with a greater energy, whilst, unless by recognising in charcoal a property which has been denied of it hitherto, that of generating salts, it must be admitted that its action is quite special, quite distinct, or that that on which its decoloring power depends is not pure charcoal, but organic or inorganic matters contained in it, capable of attracting colors.

The effects of porous bodies, and especially of charcoal, do not end here; for it has been proved that the power of the latter is sufficient to overcome even pretty strong chemical affinities. According to the experiments of Mr. GRAHAM, it possesses the property of taking oxides, not from neutral salts, on which it has no action, but from many basic salts and solutions of metallic oxides in alkalies; and in these circumstances the intimacy of the contact is such that lead and silver salts especially are reduced, and the metals set at liberty.

M. CHEVALIER not only coincides with Mr. GRAHAM as to these effects of charcoal, but even goes still further, and affirms that the action of this body extends actually to neutral lead salts, for he alleges having taken by means of charcoal all the oxide of lead from a given weight of nitrate of lead previously dissolved in water. The contradictory nature of the results obtained in reference to this point by Messrs. GRAHAM and CHEVALIER requires a new examination; but, as the latter has not shown by direct experiments how far the charcoal which he employed was pure, and free from all organic or inorganic matter, the action which he attributes to this body on nitrate of lead may be regarded as doubtful, till proof to the contrary is adduced.

It results from all these facts: 1st, That gases may be absorbed by porous bodies, as they are by water, in virtue of an action quite special, the cause of which it is not necessary here to investigate; 2nd, that charcoal is capable of decolorizing dye-baths, and taking oxides from saline solutions. But in connection with this subject, new researches are necessary to establish this property; for if the experiments of De Saussure and those of Chevreul on the different textile fibres, put it beyond doubt that gases are condensed by the fibre in the same manner as they are by charcoal, it is far from being established that charcoal comports itself like the fibre in presence of coloring matters; otherwise, like charcoal, the fibre would decolorize a bath of cochineal or madder, and the contrary is proved to be the case; it is even known that when a stuff is well scoured of foreign matters, it always fails to attract a particle of coloring matter, whilst it uniformly takes the dye in greater or less perfection if metallic oxides or spots of grease exist at its surface.

Having now enumerated the different cases of combination, all of which reduce themselves, either to a juxtaposition preceded by a change of the dimensions of a compound, or to a direct juxtaposition, or lastly, to an absorption of the liquid and gaseous bodies by the solid and porous bodies, it remains to examine to which of these phenomena the fixation of colors on stuffs appears to belong. It has been already remarked, that the formation of a color, which must be carefully distinguished from its combination with the fabric, enters decidedly into the first class of phenomena, which have been just pointed out; such, for example, is the formation of indigo-blue, that of madder-lake, and all the lakes of this description, that of chromate of lead, *et cetera*. But, this formation being effected, how do all these colored bodies remain united to the fibre? Is it in virtue of an *immediate juxtaposition*, or from the capillary force of the pores of the different kinds of fibres, which may act here in the manner of porous bodies—of charcoal, for example? In Persoz's opinion, this adherence of the colors is due to an immediate juxtaposition, the coloring matter being deposited, not in the pores of the staples of cotton, wool, and silk, but at their surface, which, as may be observed by the microscope, is composed of facets somewhat similar, in the case of wool, to the scales of fish. Indeed, if a piece of calico be dipped several times in a vat of deoxidized indigo, with the precaution of exposing this fabric to the air after each immersion, the process will result in giving it at last a most intense blue; now, if the adherence took place in virtue of the capillary force of the textile fibre of the cotton, a period would arrive when the pores, being filled, would produce no more action on the dye-bath, in which, consequently, the fibre would be no longer susceptible of being charged with coloring matter; and yet experience proves that one can always make new coatings adhere to it, the want of fixation of which only proceeds from the circumstance that they are not in immediate contact with the fibre. This phenomenon is especially remarkable in the coloration of calico by oxide of iron; for if, by successive immersions of the stuff in a ferruginous preparation, one accumulates upon it very large and very varied quantities of the iron oxide, the molecules of this last are so brought into juxtaposition as to form a concretion, just as the molecules of certain salts held in solution in water deposit themselves in successive layers, to give rise to those incrustations so well known in certain localities; and nothing can prove more clearly that the sesquioxide of iron is only a deposit at the surface of the fabric, than the facility with which one can always remove from any part whatever of one of its colored faces the whole or part of the oxide, so as to cause the white of the fibre to reappear. But, if the colors were lodged in the vessels or pores of the stuff, how could they be detached from it by an operation in some sort mechanical? How should J. M. Haussmann have succeeded, as he states in his important memoir on indigo, in decolorizing completely a piece of calico dyed with much care in indigo-blue, by leaving it to itself in the small stream which passes through his establishment. In tracing up this decoloration to its cause, this manufacturer has shown that it must be attributed to the mechanical action of the particles of silicious sand which the stream carries along, and which, by rubbing against the surface of the stuff, gradually detached from it all its colored particles. On the other hand, if the adherence of the colors is the result of a capillary action in relation with the pores, how does it happen that when the pores are lined with a colored lake, a cloth saturated with red will receive the impression of a blue color which produces the effect of black upon it, or of a yellow color which produces orange; or how does a cloth charged with blue color receive the application of a red color which produces brown, or of a yellow color which produces green? It is evident that these different phenomena can be explained only by a juxtaposition of the dyeing substances to the surface of the textile fibre. Lastly, if this adherence depended on the pores, all insoluble substances ought to admit of being lodged in these pores—the sulphate of baryta as well as the sulphate of lead—the carbonate of baryta as well as the oxide of lead—the oxide of zinc as well as the oxides of aluminum and of tin. Now, does experience prove that it is so? Does it not show, on the contrary, that some of these substances, such as the sulphate and carbonate of baryta, the sulphate and carbonate of lime, never adhere to the fibre, whatever conditions they are placed in, whilst others combine with it with the greatest readiness? In Persoz's view of the subject, these differences of results have nothing extraordinary, since, as he demonstrates in his introduction to the study of chemistry, the dimensions of the elementary atoms of bodies not being the same, their volumes are represented by the terms of two regular geometrical progressions, and hence it is natural, that not presenting all the faces similar to those of the fibre, they have not all an equal aptitude to adhere to it. It is, besides, a fact which seems to justify the influence of the dimension and form of a molecule in the fixation of coloring matters, that among the metallic oxides, those which combine with most energy with fabrics, and in conditions the least different, are precisely the hydrates of the three isomorphous oxides subjoined:—

	Cubic centimetres.
Sesquioxide of iron, the volume of the equivalent of which is	168
Sesquioxide of aluminum,	168
Sesquioxide of chromium,	168

The Editor has had occasion more than once to remark, that the compounds deposited on wool and on cotton become adherent to it in different conditions: thus, it may be advanced as a general rule that a color adheres to cotton, only in so far as it presents an alkaline reaction with it, or that the fabric impregnated with it is dipped in an alkaline bath; now, this alkaline influence is precisely that under which the textile fibre contracts. Wool, on the contrary, is strongly contracted by acids, and often it is only under their influence that one succeeds in fixing colors upon it; would it be surprising, therefore, that in the case of juxtaposition between the colors and the fibre, changes in the dimensions of the latter should contribute to the very act of the fixation?

Lastly, it may be safely inferred that the fibres ot wool, silk, and cotton, which admit of receiving the same colors without reflecting the same shades, owe this property to their configuration.

Fixation of Colors on Pyroxilized Tissues.—From the preceding remarks, it will be generally admitted that PERSOZ has fully settled the question in favor of the chemical theory of the fixation of colors; and many additional facts might be urged in support of the same view. Even organized tissues, both animal and vegetal, can and do unite, not only chemically, but proportionally or atomically, with other substances, without their organization being destroyed. A notable example of this is found in pyroxilin or gun-cotton, which is prepared by immersing cotton wool in a mixture of nitric and sulphuric acids; in the action of caustic soda on cotton at a low temperature; in the combination of chlorine with woollen, and other analogous cases.

In the *Comptes Rendus* for April, 1856, appears a series of interesting papers by F. KUHLMANN, relating the results of certain experiments which he made to discover whether cotton, modified by combination with the elements of nitric acid, or by transformation into pyroxilin, would acquire a peculiar disposition for absorbing coloring matters. The idea which seems to have actuated him in this inquiry, was the effect produced by the so-called animalization of vegetal tissues with cow-dung in Turkey-red dyeing—an effect which was formerly attributed to the assimilation of the cotton to animal or nitrogenized materials, such as silk and wool, which exhibit the greatest aptitude for the reception of colors. Since it has been found that several saline substances, particularly silicate of soda, may be successfully substituted for the dung as a means of fixing the mordants, the theory which ascribed its effect to the animalization of the vegetal tissues has been abandoned; but a new light dawns on the subject from the following experiments of KUHLMANN.

He carefully prepared a quantity of pyroxilin with cotton and linen tissues, and also with cotton wool, operating by MEYNIER'S process with a mixture of monohydrated nitric acid and concentrated sulphuric acid. The pyroxilin was washed several times with a large quantity of water, soaked for some time in a solution of crystallized carbonate of soda, and washed again. The pyroxilized tissues were prepared for dyeing by the following treatment:—They were soaked for twenty-four hours in cold water, pressed and rinsed, then soaked in boiling water, and after a fresh washing they were half-dried and calendered for printing.

Various mordants were printed simultaneously upon pyroxilized linen and cotton tissues, and upon portions of the same in their natural state, the latter having been completely freed from foreign matters by boiling for three hours in a weak solution of carbonate of soda, then washed and treated with a bath slightly acidulated with sulphuric acid, and after being washed again and half-dried, calendered to prepare them for printing.

The nitrogenized and non-nitrogenized tissues were printed at the same time with the following mordants:

Black,	Crude acetate of iron of 10° Twaddell. Thickened with starch.
Puce,	2 parts of crude acetate of iron of 15°. 1 part of crude acetate of alumina of 12°. Thickened with starch.
Red,	Crude acetate of alumina of 12°. Thickened with soluble starch.
Violet,	Crude acetate of iron of 2°. Thickened with soluble starch.
Lilac,	Crude acetate of iron of 1°. Thickened with soluble starch.
Brown,	Decoction of catechu with acetic acid. A little nitrate of copper.

After impression, the tissues were suspended for six days in the cold, and one day in the hot oxidizing chamber. They were freed from gum in a bath of cow-dung and chalk of 158° for ten minutes, well cleaned, treated a second time in the same bath at the same temperature, cleaned and rinsed. The dyeing was effected with garancin in a bath of river-water slightly acidulated, commencing with a temperature ot 95°, and rising gradually in three hours to 185°; lastly, the tissues were pressed, rinsed, and dried. The dyed samples were halved, and one-half of each bleached with chloroxide of calcium.

These operations proved the following facts:—All the nitrogenized tissues remained excessively pale compared with the non-nitrogenized ones, notwithstanding the superabundance of the coloring matter. The nitrogenized tissue, although it rejects the mordants, appears to possess the power of combining, without their aid, with a portion of the coloring matter of madder, to judge from the yellowish tint which remains even after the treatment with bleaching powder.

To ascertain whether these results were due to exceptional causes, especially to a portion of acid which might have escaped the washings, KUHLMANN repeated his experiments, soaking the nitrogenized tissues for twenty-four hours in a weak tepid bath of crystallized carbonate of soda, rinsing them, and washing them repeatedly. They were then calendered, moistened, and printed after drying. After immersion in the mordants, they were suspended in the fixing chamber for eight days. They were freed from gum, and dried in the same way as in the preceding experiment, when exactly the same results were obtained.

Other pieces of cotton, and one of linen, were heated with a hot-bath of crude acetate of iron, and then passed into a bath of nut-galls. The nitrogenized tissues acquired a very pale tint compared with those in their natural state.

Dyeing with Prussian-blue was then tried upon cotton wool. As in the black-dyeing with gall-nuts, the pyroxilized cotton only acquired a very pale tint compared with that in the natural state. The same results were obtained in a series of experiments with cotton wool, in which Brazil-wood was substituted for garancin.

M. **Béchamp's** recent experiments having shown the possibility of reducing pyroxilized cotton to its original state, **Kuhlmann** wished to ascertain whether in this case it also regained its capacity for dyeing; he found that pyroxilin, treated by **Béchamp's** process, recovered its property of receiving colors.

Happening to have retained a considerable quantity of pyroxilized cotton tissues, which were rolled up tightly, and kept in a wide-mouthed bottle closed with a cork, he observed in about two months that the bottle was filled with nitrous vapors, and that the cork, which was corroded by nitric acid, had been raised to give passage to the reddish vapors. He was unable to ascertain the cause of this spontaneous decomposition, for some pyroxilized cotton which had been dyed and preserved for the same period had undergone no alteration. He washed the decomposed pyroxilin, but its texture was greatly changed, and tore with a slight touch, and its inflammability was considerably diminished.

The results of its analysis, as confirmed by M. **Wurtz**, were as follow:—The substance was dried *in vacuo* at 212° and 230° Fahr.

Carbon,	31·25
Hydrogen,	4·08
Nitrogen,	7·88

The analyses of gun-cotton give—

	Demonte and Menard.	Bechamp.	
Carbon,	28·5	28·5	27·9
Hydrogen,	3·5	3·5	3·5
Nitrogen,	11·6	10·5	11·1

The comparison of these results shows that pyroxilized cotton, after this spontaneous decomposition, contains two-thirds less nitric acid than unaltered gun-cotton.

This partially denitrified pyroxilin was dyed with garancin and Brazil-wood after mordanting with acetate of alumina, when **Kuhlmann** was astonished to find, not only that it no longer rejected the coloring matter like pyroxilized cotton, but that it furnished infinitely stronger and brighter colors than non-nitrogenized cotton treated in the same way. Thus, with Brazil-wood and a mordant of acetate of alumina, a tint approaching scarlet was obtained, and this induced him at once to attempt the production of a nitrated cotton with the same power of fixing colors possessed by that which he had obtained by accident. After ascertaining unmistakably that the nitrous elements retained in this were in chemical combination with the cellulose, he soon perceived that these elements had not entered into such a stable state of combination, in the presence of salts of protoxide of iron, as that in which they exist in pyroxilin.

Pyroxilin, both in its decomposed and ordinary states, was exposed to a gentle heat in a bath of protosulphate of iron. In a very short time the altered pyroxilin acquired a chamois-yellow color, whilst the undecomposed pyroxilin took up much less oxide of iron than ordinary cotton under the same circumstances. The same differences of color were reproduced when the oxide of iron was converted into Prussian-blue, by a slightly acidulated bath of ferrocyanide of potassium. He thus found that pyroxilin, by losing a portion of its nitrous elements, not only loses its resistance to the absorption of mordants and colors, but actually becomes far more capable of becoming charged with these bodies than non-nitrogenized cotton. This induced him to commence a fresh series of experiments with cotton stuffs, which, before receiving the mordant, had been in contact for a longer or shorter time either with nitric acid of various degrees of concentration, or with variable mixtures of nitric and sulphuric acids. The results were very remarkable. With Brazil-wood, acetate of alumina gave violet-red tints upon non-nitrogenized cotton; immersion for twenty minutes in nitric acid of specific gravity 1·30, followed by washing with a large quantity of water, and immersion in a weak solution of carbonate of soda before the application of the mordant, gave a far deeper and less violet-red color than that taken by the cotton which was not prepared with acid. This result was confirmed by several successive trials. A very sensible effect was produced, even by the immersion of the cotton for half an hour, in the same acid diluted with double its volume of water; and in this case the tenacity of the cotton was not perceptibly altered.

In the following comparative experiments—

No. 1 was cotton without any acid preparation;
No. 2, cotton kept for five minutes in a mixture of two volumes of nitric acid of specific gravity 1·30, and one volume of sulphuric acid of specific gravity 1·85;
No. 3, cotton kept for two minutes in a mixture of equal volumes of nitric acid and of sulphuric acid;
No. 4, cotton kept for twenty minutes in a mixture of one volume of nitric acid and two volumes of sulphuric acid;
No. 5, cotton kept for twenty minutes in a mixture of one volume of nitric acid, two volumes of sulphuric acid, and half a volume of water.

After the acid baths, the stuffs were washed with a large quantity of water, passed into a bath of carbonate of soda, washed again, and finally passed into a mordant of acetate of alumina. The dyeing was effected with a decoction of Brazil-wood.

No. 1 took a pale violet-red color;
No. 2, a less violet-red tint, but still rather pale;
No. 3, a deeper and brighter color;
No. 4, a much deeper poppy-red color, very like that obtained with the decomposed pyroxilin;
No. 5, a deep red color of extraordinary richness. Under the same circumstances, but with a stronger dye-bath, a splendid red color was produced of such depth that it appeared brown. The same results were obtained in several repetitions of the experiments.

From this it evidently follows, that a mixture of sulphuric and nitric acids furnishes colors most approaching scarlet, and that the best results are obtained with a bath consisting of one volume of nitric acid of specific gravity 1·30, two volumes of sulphuric acid of specific gravity 1·85, and half a volume of water.

He also made some comparative trials of dyeing with cochineal and archil upon cotton. The mordant was acetate of alumina. Immersion of the cotton for twenty minutes in a bath of pure nitric acid, or a mixture of two volumes of nitric acid and one volume of sulphuric acid, gave with cochineal a pale red tint, very like that produced without an acid bath. The same immersion in a bath of one volume of nitric and one volume of sulphuric acid gave a much deeper color. A mixture of one volume of nitric and two of sulphuric acid gave a color of at least double the intensity of the preceding.

With the last acid mixture, also, a pretty strong color was obtained upon cotton with archil.

With garancin, a bath of nitric acid alone gave a yellower, but not a deeper tint than upon cotton which had not been nitrogenized. Two volumes of nitric and one volume of sulphuric acid gave a similar tint, but deeper than the preceding. Equal volumes of the acids gave a very fine brownish-red color, like the Turkey-red before the *avivage*, or clearing. One volume of nitric and two volumes of sulphuric acid gave the same intensity of color, but a shade more approaching orange. Lastly, twenty minutes' contact of the cotton with a mixture of one volume of nitric acid, two volumes of sulphuric acid, and half a volume of water, gave a very bright red color, of much greater intensity than the preceding.

All these experiments were repeated with wool, silk, feathers, and hair, previously submitted to the same treatment as the cotton, with remarkable results as regards the intensity and richness of the colors. Even with nitric acid diluted with five times its volume of water, the effects are very distinct.

As in treatment with concentrated acids, the threads or tissues, especially those of cotton or linen, are considerably altered, so that the preceding results cannot be generally applied in dyeing, KUHLMANN attempted the fixation upon these tissues of different nitrogenized matters produced by the action of concentrated nitric acid upon certain organic bodies. Picric acid, which does not attach itself to cotton with a mordant of alumina, gives very strong tints when the cotton has been nitrated. In this case the acid acts as a coloring matter, but it acts also as a mordant, especially in producing compound colors, either by using baths of picric acid after the application of the ordinary mordants, or by mixing the acid in variable quantities with the color in the dye-bath. The colors thus produced are very bright, but they are more applicable to dyeing upon wool and silk, as upon cotton the picric acid reacts in time upon the coloring matter, usually causing it to become yellow.

From these experiments, KUHLMANN concludes that the chemical composition of the bodies to be dyed has the greatest influence upon the fixation of color, that dyeing is a true chemical combination, and that the effects due to capillarity, and the peculiar structure of the material, are but secondary.

PRINCIPLES OF THE ACTION OF THE MOST IMPORTANT MORDANTS.—Hitherto, the term *mordant* has been applied to every substance which possesses the twofold property of uniting, on the one hand, with the goods, and on the other with the coloring matters. From this, it might appear that the mordants possess properties quite peculiar, whilst in reality it is not so. Placing oneself in the point of view which accords with the theory advanced by PERSOZ, one sees in these bodies only the elements, the constituent principles, of a saline compound which forms on the fabric itself to become adherent to it.

From the fact that the colorable and colored principles all combine with the metallic oxides to form insoluble compounds, it would seem also that these last should all be capable of fulfilling the part of mordants, and, consequently, of becoming the base of the colored lakes formed on the stuff. It is not so, however; the number of bodies which possess this property is very limited. They are, among the compounds of the inorganic kingdom, the oxides of aluminum, iron, chromium, and tin; among the products of the organic kingdom, the modified fatty bodies. The Editor has already pointed out a resemblance of the oxides of aluminum, iron, and chromium among themselves, observing that the volume of their equivalents is the same; considered under another relation, these three compounds are, of all the metallic oxides, those which exhibit in the highest degree the property of passing from a state in which they possess their full aptitude for combining, to an isomeric state in which they become indifferent in the presence of the most energetic agents.

For a body to be capable of performing the part of a mordant, it is necessary, in accordance with the views already stated, that the dimensions of its molecules be in a simple ratio to those of the surface of the fibre, and that, being fixed on the fabric, it give rise to a colored compound, the faces of which, being also in a simple relation with those of the fibre, cause its adherence.

All the mordants do not in the same manner render the colors adherent to the stuffs; some cause them to undergo only slight changes of shade, depending on the acid or basic character which the mordant performs, and especially on the dimensions of the colored molecule which is formed. Thus, let hydrate of lead, on the one hand, be deposited on a stuff, and on the other, hydrate of alumina, both colorless, but possessed of different properties, and let this stuff be passed into a bath of cochineal; the aluminous mordant will be dyed red, and the lead mordant a deep black. The same will be the case, and for the same reason, with hydrate of tin and hydrate of alumina, which, if fixed on a stuff and dyed in a madder bath, will give—the latter, a red inclining to rose-violet, the former, a red inclining to orange. The others, particularly the oxide of iron, cause the colorable or colored principle to previously undergo an alteration; for, if the iron oxide combined purely and simply with the coloring matter of the madder, for example, which in its state of isolation is of a clear brown or orange-yellow, one should obtain lakes of a clearer color than that which is peculiar to this oxide, whilst lakes are produced of which the shade varies from the most intense black to the most delicate lilac, according to the proportion of oxide on the stuff.

The nature of the principal mordants being known, the first point to be investigated is this—whether it be a matter of indifference to employ one saline combination rather than another, to render their base adherent to the goods? There are, in this question, two points to be considered: the first is one which the manufacturer should never lose sight of in the operations by which he applies a mordant on the goods, namely, the chemical part which this mordant, once fixed, ought to fulfil in presence of the coloring matter. Suppose, for example, that instead of having set at liberty on the goods hydrated alumina in that state in which it has all its chemical properties, it has, in point of fact, been deposited thereon in that state in which it loses momentarily all its aptitude for combining—the operation will be a failure, and goods thus mordanted will not dye. The second point is this, namely, that the brightness and intensity of the color which is obtained from a mordant depend on the manner in which this mordant is set at liberty, and passes into the insoluble state on the fibre, to be brought into immediate contact with it. Thus, let hydrate of alumina be prepared with every precaution, let one part of it be slowly dried, and another quickly, and there will be obtained, in the first case, a coherent mass of a horny aspect, in the second, a dull and opaque mass; and these two pieces, immersed in a solution of coloring matter of pure madder, will be dyed, the one of a red almost brown, the other, a dull and pale red. It is important, therefore, to seek, among saline combinations, that which yields most easily to the goods the base which it contains, and which is required to perform the part of a mordant, by preserving to this base all its chemical power, and the physical state most favorable to the reflection of the luminous rays.

ALUMINOUS MORDANTS.—The aluminous compounds which are used to deposit on stuffs the oxide of aluminum in the state in which it acts as a mordant, by attracting to it and fixing the coloring matter of a dye-bath, are of two kinds. In some, the alumina is in the state of a base; in others, it performs the part of an acid.

1. *In the basic state*, there are as many aluminous salts as acids, but all of them cannot be employed as mordants, those which are insoluble are taken off, by the slightest washing, from the stuff on which they are applied; such are the tri-basic sulphate, the phosphate, the phosphite, the arseniate, the borate of alumina, *et cetera.* Those which are soluble behave in three different manners: some are *basic*, or capable of becoming so by giving up a part of their acid, and therefore require to be only deposited on a fabric to yield to the fibre, either in the cold or with the aid of a temperature more or less elevated, all or part of the alumina which they contain; such are the pure or impure acetate of alumina, cubic alum, oxalate of alumina, the butyrate and the formiate. Others, either neutral or containing an excess of acid, are divided into two groups: 1st, the salts of alumina in which the oxide is not masked, and which, consequently, may always become mordants or yield their oxide to the goods when their acid is saturated with no base, or when, by the aid of another salt, by double decomposition, the formation of a new aluminous salt, insoluble and adherent to the stuff, is determined; to this category belong the sulphate, the seleniate, the chlorate, the bromate, the iodate, the bi-phosphate, the bi-arseniate, the nitrate, the chromate, the chloride, the bromide, the iodide, and octahedral alum; 2nd, the salts of alumina of which the base is masked, and which, saturated by an oxide, or mixed with another salt, would never furnish to the fabric an aluminous compound, insoluble, adherent, and capable of attracting the coloring matter. It is in this group that the tartrate, the citrate, and the malate of alumina range themselves. Thus, with the exception of these last three, it may be said that all the compounds of alumina can serve for mordants; with this difference, nevertheless, that some require only to be deposited on the stuff, at a temperature more or less elevated, to fix their base upon it, while others would remain upon it indefinitely without giving up alumina to the fabric, if by the intervention of something the base did not become free and insoluble. This will be better understood by repeating the following experiments of PERSOZ. After previously scouring with an acid from all foreign matters, the samples of calico A, B, C, D, E, he impregnated—

Sample A with a solution of acetate of alumina at 6° Twaddell;
Sample B with a solution of nitrate of alumina in the preceding liquor, and marking 12° Twaddell;
Sample C with a solution of nitrate of alumina at 6° Twaddell;
Sample D with a solution of *alum* in an acetate of alumina at 3°, and marking 9° Twaddell;
Sample E with a solution of alum marking 9° Twaddell;

and these samples, dried at the same temperature, in the same conditions, then rinsed several times in distilled water, lastly dyed in a madder bath, were found as follows:—

Sample A, charged with coloring matter of an intensity proportional to the quantity of oxide yielded to the fabric by the acetate.

Sample B—though impregnated with a preparation containing much more alumina—was dyed a much weaker shade, showing the influence of the nitrate which always renders the decomposition of the acetate a little more difficult.

Sample C, always colorless when the nitrate of alumina employed contained one equivalent of base for three equivalents of acid, and the cloth on which it was applied was entirely freed from the calcareous substances with which it is sometimes charged on coming from the operations of bleaching, which are always finished with washings in water.

Sample D, of a shade less intense, by half, than that of sample A, so that the alum associated with the acetate of alumina was a pure loss in the process.

Sample E, colorless like sample C, and in the same conditions.

When other samples, A′, B′, C′, D′, E′, were impregnated with the same solutions, but after being dried were passed into menstrua containing either bicarbonate of potassa or soda, or the neutral arseniate of potassa and a little chalk, or any other saturating body incapable by its nature of redissolving the aluminous compound which is formed; and when, as in the preceding case, all the samples had been washed and passed into a madder bath, the following was the state in which they presented themselves :—

Sample A′ had a shade of a much higher tone than sample A, the intervention of the basic compound having completed the precipitation of the alum on the goods.

Sample B′ was of a shade double the intensity of that of sample B, the alumina of the nitrate, precipitated by the intervention of the *saturating bath*, being added to that of the acetate.

Sample C′ of the same shade and tone as sample A′, for the reasons which have just been explained in speaking of sample B′, while C was colorless or very slightly tinged.

Sample D′ of a deeper dye than D, intermediate between those of A′ and B′, as being the product of the alumina of the acetate, to which was added the alumina of the alum precipitated by its being passed into the saturating bath.

Sample E′, instead of being colorless like sample E, had a tint, the intensity of which was proportional to the alumina of the alum which was fixed, that is to say, about half less intense than that of samples A and A′.

The chloride of aluminum gives the same results as the nitrate of alumina; nevertheless, as it decomposes by heat into hydrochloric acid and alumina, it gives up a part of its base to the goods when dried rather briskly, and may thus serve directly for a mordant; but this decomposition, which takes place without much danger on silk, cannot be effected on the ligneous fibre of cotton, flax, and hemp, without damaging it more or less.

The oxalate of alumina presents a peculiarity which it is the more important to point out, as it must be taken into consideration in a great variety of circumstances. At the moment of its formation, it is deprived of the property of yielding its base to the goods to such a degree, that oxalic acid is employed to remove the alumina from stuffs on which it is desired to produce a white figure; but by the prolonged contact, or instantaneously when the stuff is submitted to the action of steam—since every effect produced by time is always realized more rapidly by the intervention of heat—the oxalate of alumina undergoes a transformation, and, giving up a part of its base to the goods, becomes in this way a mordant.

Alum is, of all ingredients, the most generally employed as a mordant, and that which has been longest in use. It is impossible to go back to the period when it was introduced into dyeing; all that is known on this subject is, that in Hindostan it has been used from time beyond memory, and that in Europe, in the fourteenth century, the mode of its preparation was given by **Césalpin**; but how does it happen that this salt, which cannot by itself yield its base to the goods, should have been the first of all the preparations employed? This will be understood when one considers that several kinds of alums exist—octahedral alum, the solution of which is not made turbid by heat; and cubic alum, more or less saturated, the solution of which is on the contrary rendered turbid by this physical agent, which then precipitates on the goods sulphate of alumina; and that the ancients knew only natural alum, which always contains an excess of base, but in variable proportions. Moreover, experience taught them to effect the saturation of alum and to render it basic, since they recommend, in all their works, the addition of a certain quantity of *natron* or of *potassa* to this body when one desires to use it for mordanting goods. It is even supposed that they then associated with their saturated mordants vinegar from rice or palm—in which there is nothing improbable; for, by making use of the carbonates of potassa and soda, they must, considering the state of their chemical knowledge, have sometimes precipitated a part of the base of the alum, and to remedy this accident and redissolve this base, they had no other acid than the acetic. At a later period, the acetate of lead was introduced in the preparation of mordants of alumina, but no proof exists that it was used by the Indians; there is every reason, on the contrary, to believe that it was in Europe that this salt was first turned to account, without its being possible, however, to particularise either by whom, or at what period—doubtless because the person who first applied it was too much interested to divulge a secret to which he was indebted for results so uniform. It is well known with how much mystery manufacturers were accustomed to invest their operations at a certain period.

To the acetate of lead there were added, as old recipes prove, several substances, such as acetate of copper, chloride of sodium, arsenious acid, orpiment, realgar, chalk, *et cetera*. Some of these substances are scarcely employed at the present day; but it must be confessed that at a period when chemistry was yet little advanced, they must have had their utility, some to prevent the fixation of the iron, the presence of which in the alum might injure the purity of the red, others to preserve the color in that hygroscopic state which the printing requires, or to contribute to give to the mordant, during its evaporation, that translucid and horny appearance which is the great object to be aimed at.

So far as is known at present, the octahedral alum has always the property of yielding to the stuff on which it is applied, all or part of the alumina which it contains, when it has been previously saturated, either with the acetates of lead, lime, baryta, and strontia, which by double decomposition give rise to sulphates more or less insoluble, and to a proportional quantity of acetate; or with the acetates of potassa, soda, lithia, ammonia, and magnesia, which do not produce any turbidity in the solution of alum; or with the carbonates of the last-mentioned bases, employing the first three in such proportions that the alum passes to the cubic state without precipitation of the alumina, and the last two, which are insoluble, in any proportions.

As regards the part performed by the alkaline carbonates with which the alum is saturated, it is very simple, since these salts have the effect of forming cubic alum, which gives by heat ordinary alum and basic sulphate, but in a proportion infinitely less than when one makes use of acetate, for scarcely a third of the saturating effect is obtained from the carbonates as from the acetates; and, after reaching a certain point, no more carbonates of potassa or soda can be added to a solution of alum without its precipitating. Nevertheless, if the saturation of the alum cannot be completely effected so long as this body is free, nothing prevents its accomplishment when it is deposited on the fabric. Indeed, let concentrated solutions of alum, saturated with carbonate of potassa or soda, be printed on calico, and after thoroughly drying the stuff to precipitate the alum, let it be passed, cold, into a bath containing bicarbonate of potassa or soda, or, better still, holding in suspension the arseniate of lime and potassa—it will in that case be perfectly mordanted, and will dye as well as that on which the acetate has been deposited.

The use which has been so long made of chalk, at least by the French and other continental dyers, to saturate the alum which enters into the preparation of Turkey-red, proves the saturating effect of this body; it even appears from the writings of J. M. HAUSSMANN, that alum can be charged with one-eighth of its weight of chalk, and lose the property of becoming turbid, which must be attributed, doubtless, to a particular combination which is effected between the lime and the alumina, which have a great affinity for one another.

Having thus pointed out the part performed by the substances which unite in the formation of aluminous mordants, the composition of the principal mordants in which alumina performs the function of a base will now be indicated, and at the same time the precautions to be taken in their preparation. In the first place, the composition of two old mordants of this nature may be given as a subject of comparison:—

OLD MORDANTS.

Red Mordant—from 1760 *to* 1800.

In twenty-two gallons of water were dissolved—

55·5	pounds	alum, to which were added:
5·5	“	arsenious acid.
5·5	“	litharge.
14·0	“	acetate of lead.
1·54	“	sulphide of antimony.
1·54	“	chloride of mercury.
3·3	“	carbonate of soda.

Another Mordant—from 1800 *to* 1824.

In twenty-two gallons of water were dissolved—

49·5	pounds	alum, and to this solution were added:
5·0	“	acetate of copper, previously dissolved in one quart of acetic acid.
27·5	“	chloride of ammonium.
24·2	“	carbonate of potassa.
24·2	“	carbonate of lime.
19.1	“	acetate of lead.

NEW MORDANTS.

The composition of the three subjoined mordants is that given by M. D. KŒCHLIN in his memoir on red mordants.

Mordant, No. 1.

In twenty-two gallons of water dissolve—

88·0	pounds	alum.
8·8	“	crystals of soda—carbonate of soda.
88·0	“	acetate of lead.

Mordant, No. 2.

In twenty-two gallons of water dissolve—

60·0	pounds	alum.
6·0	“	soda crystals.
44·5	“	acetate of lead.

Mordant, No. 3.

In twenty-two gallons of water dissolve—

44·5	pounds	alum.
5·0	“	crystals of soda.
29·7	“	acetate of lead.

The following is the process adopted in the preparation of these mordants:—Into a tub containing the alum, previously pulverized, is poured the quantity of warm water required for its solution; then add to the liquor thus formed the carbonate of soda, and lastly the acetate of lead. The effect of this latter salt, which is very soluble, shows itself instantaneously; an abundant precipitate of sulphate of lead is formed. Care should be taken to agitate the whole without interruption for one hour at least, and afterwards, from time to time only; but leaving the vessel uncovered that the cooling may be as rapid as possible, for it has been observed that when the cooling is slow, the acetate being long exposed to the contact of the air, there is always a certain quantity of alumina set at liberty, which does not dissolve again. When the carbonate of soda is introduced in the preparation of red mordant, it is not a matter of indifference whether it be added to the solution of alum or to the liquid which results from the double decomposition of this salt by the acetate. In the first case, it acts on the sulphuric acid of the sulphate of alumina, and its effect is to saturate the alum and to form with it cubic alum. In the second case, on the contrary, it exerts its action on the acetic acid, giving rise to proportional quantities of acetate of potassa or soda, according to the nature of the acetate. Such a mordant may be considered as basic, and more or less deliquescent. When the mordant has cooled, and the deposit of sulphate of lead is formed, the clear portion is decanted, and is put, to be preserved for use, in vessels of glass or very compact stoneware; as for the precipitate, it is put to drain on a cloth on which it is edulcorated, and the washing waters are used for the preparation of weak mordants, or for a new operation with the same mordants.

Mr. JOHN MERCER states that the true red mordant for calico-printing is made with alum and acetate of lead or lime, *without* any chalk, carbonate of potassa, or soda; for if one of these were present, the sulphuric acid would be taken up without the possibility of its being supplanted by acetic acid. It has been proved by experience in England, that not more than two out of the three equivalents of sulphuric acid in combination with the alumina should be removed, to form a good basic sulphate. The neutralizing substance must be an acetate having the same base throughout, and next to the acetate of lead is that of lime. Alum and acetate of lime have long been generally employed in England, and they yield nearly the same and quite as good results as KŒCHLIN'S tribasic sulphate of alumina dissolved in acetic acid. Four pounds of alum and three pounds of acetate of lead are usually taken for standard red liquor, which will require six quarts of water to reduce it to working strength. Acetate of lime at 14° or 15° Twaddell, heated with three pounds of alum crystals, affords the red liquor of commerce.

For pale red mordant, only one-half of the sulphuric acid must be extracted.

It would seem, at first view, that there ought to exist in all establishments a *mother* mordant, with which all the others might be prepared by diluting it more or less with water, and making additions to it of substances suitable for the different shades; however, such is not the custom of dyers and printers, who, for the most part, prefer to prepare several kinds of mordants which differ as well in their density as in the proportions of alum and acetate of lead employed, being guided in this by the following considerations:—

1. There are few shades for which a very strong mordant is required, or one demanding a greater quantity of acetate of lead than a mordant of mean density.

2. This last, into the preparation of which less acetate of lead enters, keeps longer than a strong mordant, which soon, by decomposition in the cold, depositing more subacetate of alumina than the mordant of mean density, would not always give a constant result when diluted with water.

3. A strong mordant, in which the acid acetate predominates, would not suit in several styles of printing, especially in that which consists of two or three reds where mordants of different density are printed one on another, because then the mordants getting confounded together would produce less distinct tints.

4. The mode of giving consistence to a mordant, or of thickening, varies according to the kind of printing for which it is intended, and an acid mordant cannot be inspissated so easily as another, with any of the substances which are employed for that purpose.

5. A strong and acid mordant is less easily discharged by the operation of dunging.

In many calico-printing works in the neighborhood of Paris and Rouen, they use, for the preparation of the red mordants, sulphate of alumina, which is now manufactured in pretty large quantities. As it occurs in commerce it contains—

	Centesimally.
Sulphuric acid,	33·178
Oxide of aluminum,	17·820
Water,	49·002
	100·000

It requires, therefore, seventy-five parts of acetate of lead to effect its partial saturation, and one hundred and eighteen parts of this same salt to render the double decomposition complete, and in order that all the sulphuric acid may be precipitated in the state of insoluble sulphate of lead. Nevertheless, these proportions of acetate may vary considerably, for, as has been already remarked, the composition of the sulphate of alumina is not always the same. It is certain that the commercial article contains different quantities of acid and of base, and the manufacturer cannot exercise too much circumspection in the use of this salt, especially for certain kinds of printing.

M. D. Kœchlin prepares the red mordant with the sulphate of alumina by operating in the following manner:—

To one hundred and ten parts of a solution of sulphate of alumina, marking 52° Twaddell when it is hot, and 56° when cold, he adds one hundred parts of acetate of lead dissolved in thirty parts of water; a double decomposition takes place between these two salts, and a solution of acetate of lead is obtained, marking 24° to 26°—the most concentrated which can be obtained.

There are print-works in which the acetate is replaced by an equal weight of acetate of lead; but when one does not wish to use either the one or the other, equivalent quantities of acetate of lime, baryta, or soda may be substituted, since

2375 pounds crystallized acetate of lead are replaced either by
1600 " anhydrous acetate of baryta, or by
1708 " crystallized acetate of soda, or by
1233 " anhydrous acetate of potassa.

Hitherto, it may be said that only the acetate of lime has been employed; it would be desirable, however, that the lead compounds were replaced in the preparation of mordants by less expensive substances. The oxide of lead which exists in the acetate represents more than two-thirds of the value of the principal substances which contribute to the formation of this salt, and in using it for the preparation of a mordant, it is transformed into insoluble sulphate of lead—a plumbiferous product, in which the lead has lost almost all its value, since it is turned to account at present only for the preparation of chrome-yellow and ceruse—carbonate of lead. It was formerly further utilized to make up the vats with plumbate of lime.

If commerce supplied the market with the acetates of baryta or lime in a state of purity, the manufacturer would find a great advantage in using them, because he would leave the sulphate of lime or of baryta, the product of the double decomposition, mixed with the mordant, and these salts would contribute as a mastic to the thickening of the color.

Instead of making the mordants by the way of double decomposition, which always necessitates the employment of an acetate, the mordant of which M. D. Kœchlin indicated the preparation has long been manufactured on the large scale, and the following is the process employed:—1. Neutralize a solution of alum, saturated in the cold, with carbonate of potassa, which is added by degrees with agitation till the flakes which are formed begin to be no longer redissolved. 2. Bring this neutralized solution to the boiling point, so as to cause the formation of basic sulphate of alumina, which is collected and afterwards treated with acetic acid, wherein it dissolves perfectly, especially in the heat, furnishing one of the strongest and most reliable mordants that can be prepared and employed. But it would be too troublesome to make this preparation on a small scale and in the works themselves, since it would be necessary to throw away the water from which the basic sulphate of alumina had been separated, and along with this water the sulphate of potassa, so that all the potassa of the alum, the whole of that which served for its precipitation, and lastly, a certain quantity of the alum itself would be lost. If, on the contrary, the fabrication of this product were conducted on the large scale in an alum factory, where the water more or less saturated with sulphate of potassa might enter again continually into a new operation, there would be no loss of alkali; the basic sulphate of alumina produced would be constant in its composition, dissolving well in the acetic acid; and in this case one would economize the whole of the potassa of the alum, which might be turned to good account, and all the oxide of lead, when the acetate of this base was employed.

If the hydrate of alumina of commerce were constant in its composition, and it were always equally attacked by acetic acid, it might thus be utilized with advantage by dissolving it in this acid, since it is demonstrated by the experiments of M. D. KŒCHLIN, that the acetate so prepared is an excellent mordant.

2. *Mordants in which the alumina performs the part of an acid.*—In treating of the preparation of aluminous compounds, the composition of the aluminate of potassa or soda has been stated; it only remains, therefore, to direct attention to the conditions in which the alumina can be separated from it, and made to combine with the goods.

This oxide, which plays the part of an acid, can only be displaced by an acid. This is a rule of displacement to which all bodies of this kind are subject. The acid employed for this purpose is the carbonic acid of the atmosphere; the fabrics impregnated with the aluminate of potassa or soda are exposed in this medium, in which the potassa or the soda of the aluminate, becoming saturated by slow degrees, sets the oxide at liberty; but this result will be arrived at much more readily, by placing the stuffs impregnated with mordant in an atmosphere charged artificially with carbonic acid, or even with acetic acid, and at the same time with much moisture. By operating as is done in the print-works, it is rare that the saturation of the alkaline base by the carbonic acid is complete—they always finish, too, by passing the stuffs charged with mordant into a bath of chloride of ammonium; the alkaline base then seizes on the chlorine, and the alumina and ammonia become free; for, as they form no combination with each other, the latter remains in solution in the water or is volatilized, according to the temperature, and the former is precipitated on the stuff. Nevertheless, this method of precipitation of the alumina is not the most advantageous; it is always preferable to prolong or render more energetic the action of the carbonic acid, because the alumina set at liberty by the chloride of ammonium has never the brilliancy of that which is deposited slowly.

Applications.—The mordants of alumina are employed alone or with other mordants, for the fixation of all the coloring matters which require an intermediate agent to constitute a color, and to become afterwards adherent to the goods.

FERRUGINOUS MORDANTS.—The ferruginous preparations, like the aluminous ones, only perform the part of mordants in so far as they are soluble, and cause a deposit of oxide of iron on the stuff. The study of them is highly complicated. Iron, in fact, presents several degrees of oxidation, and it is necessary to find, not only the saline combination which best gives up its base to the stuff, but further, that which possesses, in addition to this property, the degree of oxidation necessary to attract the coloring matters without injuring the goods. The fact must not be lost sight of, that, in depositing a ferruginous preparation on the goods, the iron may be combined either in the state of protoxide, which passes by little and little to the state of sesquioxide and even of ferroso-ferric oxide—$Fe_3 O_4$; or in the state of sesquioxide, which may be hydrated, namely, in that in which it preserves its chemical condition, or anhydrous, exhibiting that modification in which it is, so to speak, unfit to perform any part; or lastly, in the state of a subsalt or insoluble neutral salt.

In a paper entitled, *Employment of pyroligneous acid in some operations of the arts*, and published in the *Annales des arts et manufactures*, M. BOSC examines in what state of oxidation iron should exist on the goods to serve as a base for black. According to this author, one should obtain on cotton a deep black tint, firm and brilliant, only in so far as use is made of a salt of iron with a base of black or protoxide, and the most favorable combination would result from the solution of the iron in acetic acid, because this acid, by the carbon which it contains, would prevent oxidation, and maintain the oxide at its inferior degree.

Arriving at the same conclusions, in a very extended memoir which treats of the fixation of the mordants of iron on cotton goods, M. H. SCHLUMBERGER establishes, first, that the acetate of iron obtained by several processes gives results very similar, and bases this proposition on the following experiments:—

He thickened with gum-water on the one hand, and with starch on the other, the following solutions of equal strength—10° Twaddell—*videlicet*,

The *first*, of acetate of iron obtained by the double decomposition of sulphate of iron and acetate of lead.

The *second*, of acetate of iron produced from a solution of iron in acetic acid.

The *third*, of acetate of iron produced by a solution of the metal in ordinary vinegar.

The *fourth*, of acetate of iron prepared by means of partially purified pyroligneous acid.

The *fifth*, of acetate of iron from which the tar had been separated by five minutes' boiling.

The *sixth*, of crude acetate of iron, containing a great excess of tar.

The *seventh*, and last, of crude acetate of iron mixed with the purified salt.

These compositions were printed in the same conditions on pieces of calico; each resulting sample was then divided into two and exposed to the atmosphere, one-half for two days only, the other for ten, before being submitted to the operation of dunging, and passed into a madder bath, when all gave a very fine violet, intense and very rich.

Although, from this result, it seems a matter of indifference which of these preparations is employed, M. H. SCHLUMBERGER points out those which should be preferred, in some localities, for certain kinds of printing. In every operation, in fact, requiring an oxidation of the protoxide of iron upon the fabric, the acetate is preferable. The crude salt, known also as the pyrolignite of iron, is more favorable for block-printing, in which the colors are exposed for a long time to the air, and where, consequently, the oxidation requires to take place slowly on the stuff; whilst the pure acetate should, on the contrary, obtain the preference for cylinder-printing, especially in those kinds of it in which the goods are immediately rinsed, and in which, consequently, the oxidation is performed rapidly.

Then advancing further, this chemist affirms, that if the acetates are oxidized before being applied to the stuff, the combination of the base with the fabric does not take place, and the iron is in great part, if not entirely, detached by the operation of dunging. If this proposition be taken in a limited sense, as embracing only the combinations of the acetic acid with the oxidized iron, there can be no difficulty in admitting it, for the sesquiacetate of iron may be considered as a solution of sesquioxide which exists in some sort in a free state, and is only fixed on the fabric with much more difficulty by reason that the acetic acid is disengaged before the salt is brought into immediate contact with the stuff. If, on the contrary, the proposition be taken in a general sense, as extending to all the salts of iron, it must be rejected as being the expression of a view which none of the following experiments confirm—experiments made by M. PERSOZ, and which do not appear to admit of any serious objection.

After preparing the sesquisulphate of iron of such purity that ferricyanide of potassium did not render the solution turbid, and that the latter, when boiled with pure oxide of copper, no longer contained any trace of iron in solution, he thickened with torrefied starch solutions of it, marking some 3° Twaddell, others 6° and 12°; he then had these solutions printed on samples of calico which were immediately dried at a temperature of 113° to 122°, then rinsed in a bath holding in suspension arseniate of lime and potassa, and lastly, dyed in a madder bath; and all these samples gave delicate violets, deep violets, and blacks, the full shades of which left nothing to desire. Experiments in every other respect similar, but in which the sesquisulphate was replaced by the protosulphate, afforded results infinitely less favorable both as regarded the shade, which was grey, and in respect to the quantity of color absorbed by the samples, and which had a bare appearance.

When an acetate is employed as a mordant, theory and practice direct that the protoacetate of iron be applied, in preference, to the goods, and this, by decomposing on the stuff, passes by slow degrees to the state of a basic salt, which oxidizes in the air; and, as it was desirable to inquire into the circumstances in which this oxidation might be effected without danger to the fabric, M. H. SCHLUMBERGER turned his attention to the question, and relates the result of experiments which he made on the four ferruginous preparations which follow, some at 24° Twaddell, and others at only 7°.

1. Acetate of iron obtained directly from the solution of iron in acetic acid.
2. Crude acetate of iron.
3. Acetate of iron obtained by the double decomposition of acetate of lead and sulphate of iron.
4. The same solution, but with an excess of acetate of lead added.

After printing these different solutions, gummed and not gummed, on as many samples as were necessary to study the different circumstances of oxidation, he exposed some, in a place with a mean temperature, to a moist air and diffused light; others in a warm situation, dry and darkened; others in fine to the rays of the sun and to all the atmospheric variations; and left in these different conditions the half of each of these samples for six days, and the other half for twenty-one days; then he passed them all into dung, to be subsequently cleaned and dyed, after which he found—

1. That the weakening of the stuff generally took place only in the samples on which the concentrated ferruginous solutions had been printed, and that in one case only, this weakening was remarked on the stuffs impregnated with a solution marking 6°;
2. That the goods were weakened by any of the four mordants mentioned above; less, however, with the last, containing an excess of acetate of lead;
3. That the pure mordants weakened the stuffs much more than those which were thickened with gum, starch, or fecula;
4. That exposure to the solar rays promotes in a given time the injurious effect on the goods, to such a degree that weak mordants, which do not attack the calico in darkness or in a diffuse light, deteriorate it very powerfully in the sun;
5. That in all the cases the weakening of the fabric does not decidedly show itself till the third or sixth day, but that at this period it is nearly the same as after the twenty-first day of the contact of the mordant with the stuff;
6. Lastly, that as the samples are passed into the dung at a boiling heat, or only at the temperature of 122°, and according as, on taking them out of this bath, they are or are not dipped into a dilute solution of chloroxide of calcium, the deterioration of the fabric is more or less decided; that is to say, it is scarcely perceptible if the samples have been cleared in a dung-bath heated to 122°, and if they have not been passed into bleaching powder liquor; and, on the contrary, it is always strongly marked when the same samples have been passed into the dung at a boiling temperature, or immersed immediately in the chloroxide.

After having thus shown, on the one hand, that this weakening of the fabric is due to the oxidation which takes place by reason of the quantity of protoxide which is deposited upon it, and on the other, that it is reduced to nothing when the mordants are weak, and is very marked when they are concentrated, M. H. SCHLUMBERGER explains this by the consecutive effects of the combination of the protoxide with the fabric, a circumstance involving disengagement of heat and electricity. M. PERSOZ accounts for this phenomenon by the fact of the momentary production of ferric acid —$Fe\,O_3$—which, as he ascertained by direct experiment, destroys the tissues with great energy when it is free in their presence.

Mr. MERCER has always considered oxygen as the cause of the *tendering* of the cotton just at the moment of its union with the protoxide of iron, and more especially when the metallic salt is in large quantity and intimately combined with the fibre. There are many instances, says Mr. MERCER, of other substances besides iron being the principal agent in the mordant, when this has taken place. A piece printed either with sulphate of iron of three pounds per gallon, or with one pound of the three converted into acetate by means of acetate of lead, then dried and passed through milk of lime, will be green; but when winced in chloroxide of calcium—bleaching powder—the iron is made buff, but the oxygen comes in such large quantity that the cotton involved is much weakened, and tears with the least effort, while the white parts of the cloth are not in the least affected.

Cloth padded with protoxide of tin dissolved in caustic potassa or soda is almost destroyed during the drying, so intense is the affinity of the mordant for oxygen.

If this same liquid, stannite of potassa or soda, be made very weak, and a strip of cotton cloth is hung half in and half out of the solution, the cotton soon becomes tendered at the surface of the menstruum, where the latter is in immediate contact with the atmosphere. This is the case when stannite of lime is substituted for that of alkali.

It is well known how difficult it is to prevent the cloth from being weakened in the Turkey-red process, by the rapid oxidation of the oil with which it is impregnated.

Many other cases of the same kind might be mentioned in which the stuff is tendered, evidently by the action of oxygen.

As it is the custom to add certain substances to the mordants with an iron base, with the view either of favoring the fixation of the sesquioxide on the cloth, or of preventing a too rapid oxidation of the mordant, or of opposing its too quick desiccation, or, lastly, of contributing to render its impression cleaner, something must be said on this subject. An opportunity will thus be afforded to speak of the researches which have been made by the scientific printer, whose experiments have just been recited, to account for the influence of these substances on the strong and weak ferruginous mordants.

The iron mordants for good blacks printed with the block have almost always a salt of copper—nitrate, sulphate, or acetate—added to them, which has for its object to facilitate the oxidation of the protoxide, and to hasten the combination of the sesquioxide with the fabric, and seems to possess, besides, the property of forming a combination with the latter, and preventing the passing of this last into that state in which it loses in some sense its chemical affinities.

The empyreumatic oil which crude acetic acid contains, and which establishes so great a difference between the acetates as regards the readiness with which they become fixed, has no other object than to retard the oxidation and prevent the action of the ferric acid on the stuff. The arsenious acid, which is employed in the violet and lilac departments, performs these two functions: on the one hand, it forms a combination with the sesquioxide, to which it preserves its chemical affinities, and, on the other, it retards the oxidation and prevents directly or indirectly the injuring of the fibre.

According to M. H. SCHLUMBERGER, the chloride of zinc which is introduced into the black mordant has no very sensible direct action on this preparation; but it opposes the tendency of the amylaceous matters employed as thickeners to coagulate; perhaps also it prevents, by combining with the sesquioxide, the isomeric modification of the latter.

The chloride of ammonium and the nitrate of potassa exercise an influence so important, that the success obtained by several manufacturers in certain kinds of printing is particularly owing to the introduction into the mordant of one or other of these substances employed in suitable proportion. Their effect appears to be, to fix the oxide more uniformly on the fabric.

The chlorates of potassa and soda perform a part nearly similar to that of nitrate of potassa.

Two ounces of saccharate of lime added to one gallon of violet mordant, render its shade clearer; first, because it precipitates a part of the oxide, and next, because the sugar more or less masks the salifiable bases. The same result is obtained with sirup of sugar—four ounces per gallon of mordant—with bitartrate of potassa, with tartaric acid, with lime juice; the action of all these bodies is precisely the same.

Oxalic acid does not injure the fixation of the iron, and two ounces of this acid per gallon of mordant do not change its shade. Acetic acid is not more opposed to it, and there are even certain operations in which its presence is necessary to maintain the oxide in solution.

Without adverting to the action of other substances, it will be sufficient in the meantime to state the results of the experiments undertaken by SCHLUMBERGER, with the view of establishing the proper degree of oxidation for obtaining ferruginous mordants of the finest fast shades.

It appears, from the researches of this chemist, that if, for fast impressions in black or violet, use is made of crude acetate of iron strongly charged with a tar which obstinately maintains the iron in the state of protoxide on the cloth, very bad results are obtained in the dyeing, whilst the same salt mixed with a certain quantity of acetate, prepared by the solution of iron in acetic acid, never gives any but good results.

To these two orders of facts—which demonstrate, the one, the inefficacy of a mordant too energetically maintained in the state of protosalt, the other, on the contrary, the efficacy of the mordant which is capable of passing to a superior degree of oxidation—SCHLUMBERGER adds others, which he adduces as affording unequivocal proof that a too advanced oxidation is always hurtful.

Thus, for example, after having steamed samples on which were printed mordants of violet and puce-color—mixture of iron and alumina—he remarked that these samples, when dyed and heightened, presented shades of a much more reddish tint than if the mordants had not been submitted to the action of the steam, which, nevertheless, appeared to him more hurtful to the puce mordants containing alumina, than to the black mordants with an iron base, and hence he concluded that this result is due to a more advanced oxidation; but PERSOZ thinks that there is here a misapprehension as to the part performed by the steam, which does not, in his opinion, set up any phenomenon of oxidation, but simply a change of physical state due to the heat, which renders indifferent a certain quantity of the oxides of iron and aluminum that are fixed on the stuff, and produce in this case, mixed with the violet—the sesquioxide, a kind of brown, and alumina, a less full shade.

Other samples, impregnated in like manner with mordants, and dipped, some into a solution of bichromate of potassa, others into a bath of bleaching powder diluted and heated to 104°, did not give better results; the tints of the samples passed into the bichromate were even more reddish than those of the specimens passed into the steam, which may be accounted for, when it is borne in mind that always when a stuff on which a protosalt is printed, is dipped into a solution of bichromate of potassa, there is a double decomposition, followed by deterioration, and consequently the formation of a compound which may be represented by a certain quantity of sesquioxides of chromium and iron; now, these acting as mordants, and the former producing brown shades, it is not surprising that one cannot obtain fine violets.

As for the action of the chloroxide of calcium, it is very simple: it modifies the physical state of the sesquioxide without changing its composition.

Foreseeing the objection, that the immersions in bleaching liquor and in bichromate of potassa, not only have the effect of oxidizing the iron, but further, by reason of the particular combinations to which they give rise, of modifying the ferruginous mordants, SCHLUMBERGER applied himself to other experiments on the mordants described in a preceding page, printing them pure or previously thickened, and exposing to the air samples of goods which were left so exposed—some for six, others for twenty-four hours, and others for two, ten, and twenty-four days.

He then observed, 1. That the mordants formed of acetate of iron—whether crude or pure—not thickened, produced on dyeing, after six hours' exposure to the air, colors which, considered in regard to their intensity, were as deep as if they had been left for twenty-one days; 2. That the same mordants, thickened, exhibited only slight differences in favor of those which were left open to the air during twenty-one days, differences which altogether disappear when one exposes for ten hours, instead of six, these same samples to the air before dyeing them; 3. That the mordants, the oxidation of which is effected in six, in ten, or in eight hours, give always, in dyeing, richer and purer tints than when these mordants have remained exposed for ten, and still more, of course, for twenty-one days, and that these differences show themselves more especially with the acetate of iron, which, not containing, like the crude salt, a substance capable of retarding its oxidation, produces always less favorable tints; and hence he concluded that it is neither sesqui- nor protoxide which is formed, but a combination of these bodies—in one word, ferroso-ferric oxide, Fe_3O_4—which is identical with that existing in nature, and known by the name of magnetic iron, or what is produced when steam is passed over the red-hot metal. In his opinion, this combination would possess sufficient stability to undergo, without losing any of its dyeing properties, the action of a temperature of 230° and even 280° Fahr. If it were so, by dissolving this complex oxide in an acid with the requisite precautions, one should find again in the solution a mixture of proto- and sesquioxides, which may be separated in several ways; for example, by boiling the solution containing the mixture of the two oxides with a certain quantity of oxide of copper, which has the property of precipitating the sesquioxide by seizing on the acid which holds it in solution, whilst it exercises no such action on the protosalt, the base of which is more powerful, and which should be found again in the liquor; but, at different times, M. PERSOZ dissolved in pure hydrochloric acid the ferruginous mordant fixed on a mordanted cloth, and never met with the protoxide in solution, after boiling it with the oxide of copper; which led him to believe that the iron exists in it in the state of sesquioxide, combined with phosphoric or arsenic acid, according as cow-dung or arseniate of lime and potassa were employed in the operation of fixing. Otherwise it would be difficult to explain how the mordanted cloth could receive, in SCHLUMBERGER'S experiments, the action of iron heated to 280° without the mordant losing its property of being dyed, which would inevitably happen if the iron existed in the state of free oxide.

According to Mr. MERCER, the best iron mordant is the crude acetate—pyrolignite—properly made, free from tar, but containing all the ethereal oils and spirit, as also the deoxidizing coloring matter, which prevent the too rapid oxidation of the iron. This mordant, combined with a proper quantity of white arsenic—arsenious acid—so as to form sesquiarsenite of iron as oxidation progresses and acetic acid evaporates, is the height of perfection for lilacs and fine plate work. The English purple plate styles from this mordant are unequalled.

To sum up, it may be affirmed, without fear of contradiction from experiment, that when solutions of iron obtained by acetic acid are applied on the stuff, with the view of making them perform the part of mordants, it is right that they be in the state of protoxide, in order that, the oxidation taking place on the cloth, there may be formed a basic acetate which will preserve to the sesquioxide its chemical properties, and pass to the state of phosphate or arseniate in the operation of dunging. It is necessary that this oxidation be slow and progressive, for, if it is rapid, the risk of the stuff being deteriorated, or of the sesquioxide passing into that isomeric state in which it becomes, as it were, indifferent to chemical agents, is incurred.

As for the other ferruginous compounds, all the acid salts are unfit to perform the part of mordants, while it is otherwise with the neutral salts, seeing that the protoxide which they contain, passing to the state of sesquioxide by absorbing the oxygen of the air, they no longer contain enough of acid to form a neutral salt, and consequently there is the formation of a basic salt which becomes fixed on the stuff. It is thus that one explains why the neutral protosulphate which remains on the calico yields to it always a certain quantity of its base, whereas, when it is acid, this phenomenon no longer presents itself. As for the sesquisalts, all those which, from any cause whatever, can pass into the state of basic salts, then become true mordants, capable of attracting coloring matters. The experiments related in a former page with samples A, B, C, D, E, apply here also; but it must not be forgotten that in all these salts the sesquioxide does not exist in the same state of condensation—that in some, as the phosphate and arseniate, there is only a very weak tint, and in others, as the nitrate, chlorate, and acetate, this hue is on the contrary very intense; now, it is demonstrated that in this last state the sesquioxide, having little affinity for coloring matters, gives only bad shades. When, for example, one imprints on the cloth a solution of sesquinitrate, the oxide which separates in the state of a basic salt is dyed with much difficulty, and produces only tints which are brown instead of being of a blue shade.

When the iron is in contact with the calico in presence of moist air, it produces, by oxidizing, spots of rust, which become fixed on the cloth, and attract the coloring matters. In the same circumstances, the protosulphide presents the same result, either from the circumstance that, passing first into the state of sulphate by an absorption of oxygen, it is immediately transformed into a basic salt by fixing a higher proportion of oxygen, or that it has directly the power of fixing by a double decomposition a certain quantity of coloring matter.

The alkaline mordants of Iron.—Hitherto few besides **Haussmann** have employed as mordants alkaline ferruginous solutions. He dissolved iron or its protosulphate gently in dilute nitric acid, under which conditions there was always the formation of an ammoniacal salt, which the Editor thinks the following equation explains:—

$$\underbrace{8\,Fe}_{\text{Iron.}} + \underbrace{19\,NO_5}_{\text{Nitric acid.}} + \underbrace{4\,HO}_{\text{Water.}} = \underbrace{5\,(Fe_2\,O_3,\,3\,NO_5)}_{\text{Sesquinitrate of iron.}} +$$

$$\underbrace{NH_4\,O,\,NO_5}_{\text{Nitrate of ammonia.}} + \underbrace{NO_2}_{\text{Binoxide of nitrogen.}} + \underbrace{NO}_{\text{Protoxide of nitrogen.}}$$

The liquor obtained was afterwards saturated with carbonate of potassa, which was poured in very cautiously; the precipitate which formed at first was soon redissolved by an excess of carbonate of potassa, giving rise to a double salt which was decomposed by the alkaline oxides, these precipitating sesquioxide. **Haussmann** states that he used this solution with success in many circumstances.

Persoz is satisfied of the property which sesquiphosphate of iron possesses of being dissolved in the alkalies, and particularly in ammonia, so as to compose an excellent alkaline ferruginous mordant, which prints with clearness, and which may be dyed immediately after printing. If a solution of phosphate of soda —$2\,NaO,\,HO,\,PO_5$—be poured into a solution of sesquisulphate of iron, there is formed an abundant precipitate of sesquiphosphate of iron of a slightly yellowish-white, which being collected and washed, dissolves very well in ammonia. This solution being thickened and then printed, nothing more is required but to dry the goods briskly, to set up a combination between them and the mordant. When this has taken place, it is sufficient to rinse the goods in water, and to pass them afterwards into a bath of madder dye, to obtain the purest lilac and violet tints; and what is rather remarkable, is the circumstance that stuffs thus mordanted will even admit of being dyed in a spent madder-bath, in which fabrics mordanted in the usual manner would no longer be dyed—a result which must be attributed to the double decomposition which takes place in such a bath.

Applications.—The ferruginous mordants are employed alone, or mixed with those of alumina. In the first case they serve, with the red coloring matters, to produce on the stuff, greys, lilacs, violets, and blacks; with the yellow coloring matters, greys, olives, more or less deep, verging to black; and with a mixture of red and yellow coloring matters, a multitude of shades, from clear grey even to the deepest black. When associated with aluminous mordants, the ferruginous ones give, with red coloring matters, puce shades more or less intense, verging on black; with yellow coloring matters, yellows more or less olive, according as there is more or less of the iron mordants; with a mixture of red and yellow coloring matters, brown colors, dead leaves, rotten wood, *et cetera*, which vary *ad infinitum*, according to the respective proportions of the mordant of alumina and the mordant of iron, or those of the coloring matters of which the dye-bath is composed.

Stanniferous Mordants.—Tin by uniting with oxygen gives rise to well-marked oxides, one of which reacts as a powerful base, the other as an acid, and both of which are applicable as mordants. It may even be said, that of all the metallic compounds, the stanniferous combinations are those which adhere to the goods with the greatest energy. The best proof which can be given of this is, that even when a lake with an aluminous base is already formed on the goods, one can always remove the base, in whole or in part, by placing the stuff which is impregnated with this lake, under suitable circumstances, in presence of a compound of tin. The choice between a stannous and a stannic salt, is determined by the nature of the goods, and by that of the colors which it is desired to fix upon them. It will here be sufficient to consider the conditions in which these compounds must exist.

Of those which are employed for manufacturing purposes, there are some in which the oxidized tin performs the part of a base, and others in which it has the function of an acid.

I. *The compounds in which the oxidized tin performs the part of a base* are of two kinds: some having a base of protoxide, and others of binoxide. Among the former it is the protoxide which is in most general use; it cannot be deposited on the stuff without giving up to it a certain quantity of its base, seeing that when treated with water it undergoes a partial decomposition, and is transformed into an acid salt, which remains in solution in that medium, and into a basic insoluble compound which adheres to the fabric. Printers very often turn the salt to account along with a certain quantity of acid, to prepare the calicoes which they intend to receive the printing of *steam-colors*. As the chloride of tin employed in this manner acts only by a double decomposition which it produces in the water, whence there always results a certain quantity of hydrochloric acid, which becomes free, it is not uncommon to see stuffs, especially cotton stuffs, more or less injured by the acid. To prevent such accidents, one may apply with success, for the fixation of the protoxide of tin, the property which the acetates possess of acting in the manner of bases. For this purpose, when the goods have been padded in a bath of protochloride of tin, they are passed into one of acetate of potassa or soda, from which they are withdrawn by expressing them between two cylinders.

Bancroft employed, instead of chloride of tin, a solution of the protosulphate in hydrochloric acid, which decomposed still more easily in presence of the goods. The following is the manner of preparing this solution:—

On twenty-two pounds of granulated tin, introduced into a vessel of porcelain, stoneware, or glass, pour thirty-six pounds of hydrochloric acid of commerce, free from iron. Add by little and little to this mixture, 16·5 pounds of sulphuric acid at 150°; there is development of heat, and the tin is at first attacked with violence, but as it dissolves more slowly, in proportion as the liquor becomes concentrated, the mixture is heated, to complete the solution, in a sand-bath, until it disengages no more hydrogen gas. The whole being then left to cool, a saline mass is obtained, which contains a slight excess of tin; the liquor is decanted; the remaining metal is weighed to know how much has been dissolved, and this quantity being known, the liquor is diluted with just so much water that its weight may be eight times that of the tin dissolved, that is to say, one hundred and sixty pounds, for example, if there have been twenty pounds of tin dissolved.

These stannous salts—chlorides and sulphates—of which a great quantity is consumed, are often prepared in the print-works; but, from the difficulty of procuring vessels of stoneware or glass capable of bearing the action of the heat without cracking, these are substituted by tin boilers; and as these boilers themselves may melt when heated without sufficient precaution, M. J. **Fries** conceived the idea of covering internally a copper boiler with a thick coating of tin, which gave him two concentric boilers soldered together, the one of copper, to resist the action of the fire, the other of tin, to preserve the copper from the action of the acids.

These compounds are likewise prepared by raising to the temperature of 212°, in a water-bath, any quantity of Nordhausen sulphuric acid, in which is dissolved, to the point of complete saturation, protochloride of tin. The solution takes at first the consistence of a thick sirup, and afterwards the appearance of an indurated mortar. This preparation ought to be kept protected from contact with the air.

Among the compounds of binoxide of tin, there is a multitude of preparations which are employed as mordants or constituent parts of the lakes which are applied on the goods, and which contain binoxide, either pure or mixed with protoxide. They are generally designated by the name of *tin compositions.* Some of these are subjoined:—

1st. 22 pounds of tin in ribands are dissolved with precaution in a mixture formed of
55 pounds nitric acid and
120 pounds hydrochloric acid of commerce.

2d. 22 pounds of granulated tin are dissolved in a mixture formed of
44 pounds hydrochloric acid of commerce,
44 pounds nitric acid of commerce, in which has been previously dissolved
11 pounds chloride of ammonium.

3d. 22 pounds of tin in ribands are gradually dissolved in
176 pounds of nitric acid at 40° Twaddell, in which has been previously dissolved
22 pounds chloride of ammonium.

4th. 22 pounds of tin are dissolved in
22 pounds nitric acid at 62° Twaddell,
44 pounds hydrochloric acid,
44 pounds water.

5th. 22 pounds protochloride of tin are dissolved by degrees in a mixture formed either of
35 pounds hydrochloric acid, or
17·5 pounds nitric acid;

or of
17·5 pounds hydrochloric acid and
6·5 pounds nitric acid;

or, lastly, of
11 pounds hydrochloric acid, or
15 pounds nitric acid.

6th. 22 pounds protochloride of tin are gradually dissolved in
27·5 pounds nitric acid.

Further, in a mixture formed of—

7th. 22 pounds nitric acid, and
22 pounds hydrochloric acid,

as much tin is dissolved as these acids can reduce; and then heat is applied to dissolve in this liquor previously decanted,

2·2 pounds protochloride of tin.

8th. 22 pounds of tin are dissolved with caution in
42 pounds nitric acid at 64° Twaddell,
33 pounds hydrochloric acid at 36° Twaddell; the solution being effected, add
5·5 pounds acetate of lead.

Lastly, protochloride of tin is dissolved by small portions at a time, to the point of saturation, in nitric acid at 66° or 68° Twaddell. The resulting solution has the consistence of a jelly.

From these examples one may see how such preparations vary in their composition: it appears also that it would be more advantageous for the manufacturer to make them directly, by mixing bichloride of tin in suitable proportions with chloride of ammonium. As for the acetate of lead which is seen figuring in one of them, it has no other object than to diminish the corrosive action of the excess of acid which it contains.

The only preparations of tin used by English calico-printers are—

1. Protochloride of tin in crystals.
2. Protochloride in solution at 120° Twaddell.
3. Bichloride of tin in solution at 120° Twaddell.
4. Pink salt—chloride of ammonium and tin.
5. Stannite of soda.

These are generally purchased from the chemical factories in the neighborhood of the printworks.

II. *With reference to the compounds in which the oxidized tin performs the part of an acid.*—These mordants are of frequent use; they are prepared by dissolving protoxide of tin, or, for greater economy, protochloride, in hydrate of potassa or soda. These bases form with chlorine, alkaline chlorides, and the stannous oxide set at liberty combines with the excess of base to give rise to a soluble stannite.

This compound has but little stability; two powerful causes tend to decompose it. The first consists in the action exerted upon it by the carbonic acid of the atmosphere, which seizes on the alkaline base, and sets at liberty the protoxide of tin, which, uniting with the oxygen of the air, passes into the state of binoxide. The second cause is found in the disturbance of its molecules; for even when protected from contact with the air, the atom of protoxide divides into two, and is transformed into binoxide and metallic tin, according to the formula—

$$2\,\mathrm{Sn\,O} = \mathrm{Sn\,O_2} + \mathrm{Sn};$$

but the last, which remains entire so long as it is not exposed to the influence of the air, oxidizes when in presence of this agent, and passes by degrees to the state first of protoxide, and then of binoxide. Thus, in brief, from one or other of these causes, the stannite always furnishes to the stuffs which are impregnated with it, binoxide of tin. Further, as will be readily conceived, the displacement of the oxide is always favored by the intervention of the sulphuric acid, which, seizing on the base, sets the oxide at liberty, and accelerates its oxidation.

Applications of the Tin mordants.—Recourse is but rarely had to the mordants of tin to obtain *dyed* colors, or those termed *maddered;* they are only used to combat the effects of the iron or red mordants, or, after the dyeing is effected, to transform, by substitution, a lake with a base of alumina into another lake with a stanniferous base; but if the use made of them is limited in this department, they figure in almost all the so-called colors of *application*, and especially in *steam-colors.*

It is the binoxide of tin which gives to the coloring matter of cochineal that scarlet hue which no other colorless oxide can make it contract. With the tinctorial matter of madder it forms a fire-red lake, whilst a mordant of alumina produces, with the same matter, only a rose lake tending to violet.

Other mordants are likewise used to fix the colors on fabrics, as compounds with a base of sesquioxide of chromium. But although the latter oxide, isomorphous with alumina and sesquioxide of iron, is susceptible of adhering to the goods and attracting the coloring matters, it gives rise by its greenish-grey shade to lakes which are not clear in the colors, as will be seen by examining the tints obtained from this oxide, by passing the stuffs impregnated with it into a bath of Campeachy, Brazil-wood, madder, or quercitron.

These compounds, as well as those of some other metallic oxides, not being in general use, do not require to be minutely discussed in this place; and with reference to the fatty organic mordant which plays so important a part in the Turkey-red department, its action has been already examined in treating of that particular color.

STATISTICS.—In the Jury Report on that department of the Great Exhibition of 1851, which relates to the subject of this article, it is justly remarked that the art of dyeing has participated in the great industrial movement of the last twenty-five years; and of this the dyeing of mixed fabrics, composed of animal and vegetal substances, affords a striking proof. The great difficulty of presenting a bright, sound, and uniform color on fibres having different affinities has been overcome. In the various modes of dyeing silk and wool, Prussian-blue, with a tin mordant, has been substituted for indigo with complete success. The colors extracted from various dyewoods have, by a judicious application of oxidizing agents, been rendered brighter and more permanent. Preparations of tin, formerly employed for fine colors only, are now in general use, and furnish the means of multiplying the shades of bright and permanent hues.

The following table exhibits the amount of some of the most important dye-stuffs imported and exported during the last four years:—

	IMPORTED.				EXPORTED.			
	1852.	1853.	1854.	1855.	1852.	1853.	1854.	1855.
Cochineal, ...cwts.	22,042	10,160	19,341	27,478	8,964	11,178	14,475	13,691
Indigo, ... “	83,565	66,409	70,173	59,760	67,184	59,588	50,550	64,167
Lac dye, ... “	17,631	18,050	16,871	9,424	6,955	6,053	4,627	6,121
Logwood, ...tons.	19,669	20,752	27,217	30,215	2,225	1,709	2,529	4,563
Madder, ...cwts.	84,385	111,563	102,723	100,251	..	..	..	..
Madder root, ... “	179,812	215,017	183,666	175,046	..	..	..	..
Sumach, ...tons.	9,758	10,836	11,524	13,082	..	..	..	..
Catechu, ... “	3,244	3,904	4,547	5,322	241	538	682	950
Cutch, ... “	2,236	485	1,915	2,361	528	456	510	975
Valonia, ... “	13,870	17,179	19,886	10.838	..	..	..	..

The duties on cochineal, after being reduced in 1842 to one shilling a hundredweight, were finally abolished, along with the duties on other dye-stuffs, in 1845. The consumption may perhaps be estimated at about twelve thousand hundredweight, or one million three hundred and forty-two thousand pounds. The price of this article has been liable to great fluctuations; in 1814, it was as high as thirty-six shillings and thirty-nine shillings for the best, and in 1853 it had fallen to from four shillings to six shillings and fourpence per pound. Previously to the war, which terminated in 1815, it had never been under twelve or thirteen shillings.

The consumption of indigo has varied but little in this country during the last ten or fifteen years, having been, at an average of that period, about two million pounds a year. This stationary demand, remarks the late Mr. MACCULLOCH, notwithstanding the fall in the price of the drug and the increase of population, is chiefly to be ascribed to the decreasing use of blue cloth, in the dyeing of which it is principally made use of. The following is believed to be a pretty accurate estimate of the average annual production of indigo in India, in maunds of eighty-two pounds:—

	Maunds.
Bengal, ...	77,431
Tirhoot, ...	23,168
Benares, ...	13,775
Oude, ...	7,525
Total, ...	121,899

Of seven million eight hundred and ninety-four thousand four hundred and ninety-seven pounds of indigo imported into Great Britain in 1841, seven million four hundred and fifty-six thousand six hundred and seventeen pounds were from India, one hundred and four thousand one hundred and ninety pounds from the British West Indies, one hundred and seventy-eight thousand seven hundred and twenty-seven pounds from Guatemala, sixty-eight thousand three hundred and four pounds from Colombia, *et cetera.* Of the total quantity imported, two million seven hundred and eighty thousand five hundred and eighty-three pounds were retained for home consumption. The price of Bengal indigo of medium quality has varied at different times from three to six shillings per hundredweight.

Lac dye, which is the coloring matter extracted from *stick lac*, is formed into small square cakes, like those of indigo. Its use has been extending in this country, notwithstanding the continued fall in the price of cochineal. The annual consumption may at present amount to one million five hundred thousand pounds. The duty on this substance was formerly five per cent.; but in 1842 it was reduced to one shilling per hundredweight, and, as with other dye-stuffs, was totally repealed in 1845. The prices vary from one shilling and eightpence to two shillings and sixpence per pound.

Logwood is an article of great commercial importance. The entries for home consumption, at an average of the three years ending with 1842, amounted to eighteen thousand seven hundred and thirteen tons a year. The old duty of four shillings and sixpence per ton on foreign logwood, and of three shillings on that from a British plantation, was reduced in that year to two shillings a ton, and repealed in 1845. Its price in the London market varies from six to nine pounds per ton, according to quality.

The imports of madder are principally derived from France and Holland, and those of madder roots from France, Italy, and Turkey. A duty of six shillings per hundredweight on the former, and of three shillings per hundredweight on the latter, was repealed in 1845. The price of madder varies from twenty-five to sixty shillings per hundredweight.

Almost the whole of the sumach imported into this country is obtained from Italy. About ten thousand tons are retained for home consumption. The price varies from nine to eighteen shillings a hundredweight. The duty of one shilling a ton was repealed in 1845.

The duty on valonia, after being reduced in 1842 from twenty shillings to five shillings a ton, was repealed in 1845, with the duties on other dye-stuffs. The price of this article, of which it will be seen from the preceding table that a very large quantity is imported, varies from twelve pounds to sixteen pounds per ton.

It is difficult to procure reliable statistical information on the subject of dyed goods, except in connection with the art of calico-printing; and even on this latter subject, so important in a national and commercial view, there are no official returns. It is, therefore, fortunate that Mr. EDMUND POTTER, to whom the Editor has already acknowledged his obligations for many historical details of great value, has likewise devoted his attention to the statistical department, and has kindly authorized the Editor to freely avail himself of the facts which were stated in his able lecture before the Society of Arts in 1852, and of which, so far as relates to this subject, the following is a condensed statement:—

The present annual production of printed cloth of all kinds—namely, calico, muslin, delaines, in the woollen and cotton fabric, and printed woollens—is estimated by Mr. POTTER at about twenty million pieces. He acknowledges that he arrives at this estimate with considerable difficulty, owing to the absence of any very authentic statistics. Commencing at the repeal of the duty in 1830, the excise return gives eight million three hundred thousand as the production of that year. In 1840, it was estimated to amount to about sixteen millions. Since that period, no means exist of coming to so accurate a conclusion. Mr. POTTER's own experience, however, and that of others upon whose judgment he can fully rely, lead him to suppose that the present annual production exceeds twenty millions of pieces, and consumes a weight of cotton about one-seventh the entire import of the raw material into this country.

In reference to the exports of printed goods, the only information supplied is rather obscure, owing to their being classed with dyed cloths of all kinds; a custom which, it is hoped, may be altered, as producing unnecessary confusion. After much research and calculation, Mr. POTTER ventures to estimate them for 1851 at fifteen million five hundred and forty-four thousand pieces, or rather more than three-fourths our entire production. These goods are, however, many of them, of the cheap and more staple class of prints, or slight goods suited to warm climates, and for markets where cheapness is the great recommendation. In value, he is disposed to estimate the export of printed goods at five million seven hundred and seventy-five thousand pounds.

In reference to the entire export of manufactured cotton goods—exclusive of yarns—it may be assumed that out of twenty-three million four hundred and forty-seven thousand one hundred and three pounds, given as the export of 1851, about one-fourth may be placed to the account of the print trade.

These exports may be divided, as nearly as is useful for the purposes of comparison and reference, amongst the following countries:—

ESTIMATED EXPORTS OF PRINTED GOODS FROM GREAT BRITAIN IN 1851.

	Pieces.
Hamburg and North Germany, large portion in transit,	900,000
Holland,	360,000
Belgium,	30,000
Denmark,	22,000
Sweden and Norway,	36,000
Russia—Odessa only,	14,000
France—in transit,	50,000
Naples and Sicily,	230,000
Sardinia, Tuscany, Trieste,	720,000
Turkey, Ionian Isles, Greece, Malta,	1,440,000
Egypt,	84,000
Gibraltar and Spain,	280,000
Portugal, Madeira,	410,000
Chili and Peru,	1,010,000
Mexico,	270,000
Brazils and East Coast of South America,	2,680,000
British West Indies,	660,000
Foreign West Indies,	690,000
St. Thomas,	450,000
British North America,	470,000
United States,	1,470,000
India,	1,570,000
China, Manilla, and Singapore,	550,000
Mauritius and Batavia,	325,000
Coast of Africa and Cape of Good Hope,	505,000
Australia,	237,000
New Zealand and South Sea Isles,	36,000
California,	45,000
Total,	15,544,000

The home consumption for 1851 was estimated at four million five hundred thousand; the excise returns for 1830 gave it as two million two hundred and eighty-one thousand five hundred and twelve pieces. The repeal of the duty, and the decrease in the cost of production, giving the consumer goods in much better taste and value at one-half the price, must have greatly tended to this increase.

The following is given as the number of print-works in Great Britain and Ireland, *exclusive of the London district*, in 1851:—

England—Lancashire,	120	= 202
Scotland,	81	
Ireland,	1	

The only records which Mr. Potter possessed of a former period were from a table compiled for private reference, by a friend in the trade, in the year 1840, and which he had then occasion to make use of and verify. This did not include London, and the numbers were—

Lancashire,	93 firms.
Scotland,	70 "
Ireland,	3 "

The Lancashire number shows an increase of twenty-seven firms, and Scotland of eleven, during that interval. This increase is comparatively small, when contrasted with that of the cotton trade generally, and it is really more insignificant than the figures represent, since the new establishments are almost all very small ones, many of them employed in printing the different fancy woollen and mixed fabrics, carpets, and yarns. It is an extraordinary fact, that for the last twenty-five or thirty years in the Lancashire district, no more than one or two new print-works of any great extent or power have been erected, while a greater number of large establishments have been discontinued. The power, then, by which the annual production has been raised from eight to twenty millions, has been chiefly gained by the extension of existing establishments; certainly the increase of producing power has been equivalent to the increase of demand.

There were three printing establishments in Ireland in 1840, but they have since been closed.

The rate of wages paid to the hands employed in the trade is believed to be higher than that of any other class in the cotton trade. Their occupation requiring from many of them a knowledge of chemistry and of art to some extent, and the constant exercise and appreciation of correct execution, enables them to rank amongst the highest class of manufacturing workmen.

Mr. Potter regrets that he can offer no official statistical returns as to the production of foreign countries. In connection with his office as reporter for the jury on printed goods in the Exhibition, he made every effort, through his friend, M. Persoz of Paris, one of his colleagues on the occasion—a gentleman whose varied knowledge on all subjects connected with French calico-printing cannot be too highly rated—to obtain reliable returns on that subject, but without success. The only estimate to which any reference can be made, is one of the late Mr. Thomson's in 1840, in which he calculates the then production of France to be little short of three million five hundred thousand; and if it be considered to have since increased one million, her trade of four million five hundred thousand pieces per annum—taking into view the high quality of a large proportion of her productions—may be ranked as a very important one. France, after ourselves, is placed highest in the scale in *value* of production, and next to the United States in *quantity*. She is, indeed, the only competitor which this country has to meet in any of the neutral markets of the world. This position she holds in fine goods only, and chiefly so by her taste. The United States exceeds France in *quantity* of production, and her consumption of printed goods is certainly more per head for her population, than that of any country in the world; but her printing is more remarkable for mechanical power and speed than for taste; her mode of business, forced in many instances by large capitals on the joint-stock system, varies completely from that of Great Britain. Her cost of production is also much higher, from her high-priced labor, coal, and drugs. She protects herself with a twenty per cent. duty, and competes with this country only in her own market.

The Zollverein, Austria, and Bohemia, produce for their own markets; and by their protecting duties prevent any other supply, except of very fine French goods. Their prints are good in execution, imitations of French taste in the finer goods, and of English prints in the medium and lower qualities.

Switzerland is very limited, but choice, in production, and opens her market to the world, with a fiscal duty of only two and a half per cent.

Holland has a small production of medium goods, and a very moderate protection, not exceeding five per cent. Belgium is highly protected, and produces nothing deserving notice in quality.

Naples has a few small print-works, and high protective duties.

Russia produces printed goods of no great character, and her market is prohibited to the British, except the port of Odessa. Spain likewise produces goods of an inferior quality to a limited extent, and prohibits imports, except in goods of a very fine quality, at a duty of fifty per cent. Occasionally, a large trade is done in English prints through the smugglers, chiefly from Gibraltar.

Portugal produces very slightly, and imports English goods at a duty of about thirty per cent.

Turkey produces a few printed goods, hardly worthy of criticism. Her duties are light—not above three per cent. Egypt has likewise revived the art, and with the assistance of European machinery and workmen produces the rudest possible results; duty as in Turkey.

Of the productions of all other countries, it may be fairly stated—with the exception of those of China, the East Indies, and the negroes—that they are imitations of either French or English goods, and cannot any of them be said to have a school of their own. The Chinese undoubtedly practised the art of calico-printing many centuries before it was known in Western Europe; but their productions exhibit a very primitive taste and rude execution.

In conclusion, Mr. Potter is inclined to think that the production of Great Britain in printed goods exceeds that of all the rest of the world.

ELECTRO-METALLURGY.—*Galvano-plastique,* French; *Galvano-plastic,* German.—This is the art of depositing metals from solutions of their salts, upon metallic or other conducting surfaces, by the agency of voltaic electricity; the metal thus deposited forming a compact body, similar to that obtained from the most improved metallurgical operation. Electro-metallurgy is a generic name, under which are included many specific processes, all more or less resembling each other, and dependent upon the same principles. In the earlier career of this very modern art, it was prosecuted chiefly as a pastime by thousands, under the name of the *Electrotype;* but it was not long confined to this superficial application, for by the skill and enterprise of such men as the ELKINGTONS of England, and RUHOLZ of France, it was speedily added to the industrial arts of both countries, and continues still to receive fresh developments in the number, usefulness, and beauty of its applications. Among these may now be enumerated its employment for the reduction of metals from their ores, for the analysis of alloys, electro-coppering, electro-silvering, electro-gilding, *et cetera;* for the multiplication of fac-similes of coins and medals; for copying seals and plaster casts; for making dies, busts, and statuettes; for obtaining, in metal, perfect copies to any extent, of various kinds of sculpture, of fruits, vegetals, insects, and other natural objects; for plain and engraved copper plates, steel plates, and woodcuts; for etching, and other important purposes, too numerous to be here detailed.

Although BRUGNATELLI experimentally practised gilding by galvanism in 1805, and more than thirty years afterwards, Professor DANIELL, when operating with his constant battery, and Mr. DE LA RUE, in the same circumstances, found that copper was deposited from its sulphate solution, and took the impression, however minute, of scars or scratches on the plate to which it adhered—yet it was reserved for JORDAN, SPENCER, and JACOBI, about the year 1839, to show the important applications of such phenomena to the arts. In fact, the art of electro-metallurgy may be said to date its origin from that period.

Its early history is interesting, and, as in many other cases, different claimants for the honor of the discovery have appeared; but before entering into any details on that subject, it will be desirable to place before the reader the principles on which it is founded. Even the facts of its discovery cannot be understood without a preliminary knowledge of certain electrical phenomena produced by chemical action, on which it is dependent for its existence, and of which it may be considered a branch. The name alone indicates its intimate connection with that mysterious agent which operates alike in the thunderstorm and the electric telegraph; which literally pervades all nature, as well as so large a department in the field of modern art; and which is, in fact, the motive power in electro-metallurgical operations. It is obvious, therefore, that, without a sufficient knowledge of the principles of galvanic action, or, in other words, of that development of electricity produced by chemical decompositions, the principles of electro-metallurgy cannot be intelligible to the reader; and hence the necessity of introducing the subject with a summary of the nature of galvanism and galvanic batteries.

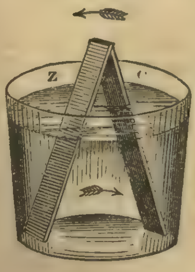
GALVANISM.—This term, which, as already stated, is applied to that development of electricity produced by chemical action, is derived from the name of its discoverer, GALVANI, professor of anatomy at Bologna, whose experiments on the convulsive effects produced by electricity on the muscles of dead animals, first drew attention to the subject. It is also termed *voltaic electricity,* in commemoration of the discovery of the voltaic pile by Professor VOLTA, of Pavia, who first established the identity of galvanism and ordinary electricity.

The history of the discovery of galvanism is not a little remarkable. The brilliant series of discoveries which had been made by the electric machine and batteries of Leyden jars had just ceased to excite the philosophical world, when the following singular circumstance is said to have occurred. Madame GALVANI had been in declining health, and was directed by her medical adviser to try the nutritive effect of stewed frogs. A dish of these animals, already dressed for cooking, lay on the table at the same time that a few of the Professor's pupils were amusing themselves by taking shocks from an electric machine. Madame GALVANI, keeping her eyes upon the delicate morsels, was struck with the frogs exhibiting convulsive movements when the machine was in action; she also observed that the blade of the knife which lay upon the edge of the dish touched some of the little animals. She kept her observation private till the return of her husband, who was delighted with the information, repeated and varied the experiments, and thus laid the foundation of the science of galvanism. This is one account of the matter. It is stated, however, by GALVANI himself, in a work published at Bologna in 1791, for the Institute of Sciences, that he was dissecting a frog on a table, whereon stood an electric machine, when the limbs suddenly became convulsed by one of his pupils touching the crural nerve with a dissecting-knife at the instant of taking a spark from the conductor of the machine. The experiment was repeated several times, and it was found to answer in all cases when a metal conductor was connected with the nerve, but not otherwise. He observed that muscular contractions were produced by forming a connection between two different metals, one of which was applied to the nerve, and the other to the muscles of the leg. This observation was made in 1790, and similar phenomena having been found to arise when the leg of the frog was connected with the electric machine, it could scarcely be doubted that in both cases the muscular contractions were produced by the same agent. GALVANI, who had long entertained the opinion that muscular action is attributable to electricity, looked on this phenomenon as a confirmation of that peculiar opinion, and pursued the inquiry with great zeal. From a course of experiments he drew the erroneous inference, in accordance with his preconceived hypothesis, that the muscular contraction was caused by animal electricity, that the muscle and the nerve were in the condition of the inside and the outside of a charged Leyden jar, and that the metallic connection merely served the same purpose as a discharging wire, by giving the two electricities the means of combining.

Galvani's investigations on this subject were no sooner made known to the scientific world, than they excited general interest; his experiments were varied in all possible ways; but his conclusions were objected to by many philosophers, among whom was Volta, who, from his researches, came to the conclusion that electricity was the effect of contact of dissimilar metals, and by arranging a series of zinc and silver plates formed what is termed the pile of Volta, or the voltaic pile. This apparatus greatly extended the means of producing electrical phenomena. All the combinations, indeed, now known as galvanic batteries, spring from, and may be considered as modifications of Volta's pile, which was discovered in 1800.

To illustrate the nature of the action in these galvanic arrangements, the simplest process is to take two plates of different kinds of metal, and place them in a fluid capable of exerting some chemical action on one of the plates, while it has little or less action on the other, and then to establish a communication between them by their direct contact with one another, at some point either above or beneath the surface of the liquid. Thus, let a plate of zinc and a plate of copper be partially immersed in dilute sulphuric acid, contained in a glass vessel, and let it be supposed that, in the first place, no communication is established between the two plates. In this case the zinc, being the more oxidizable metal, becomes rapidly dissolved, while the copper remains unaffected; an extrication of hydrogen appears at the surface of the zinc, arising from the decomposition of the water, the oxygen of which unites with the metal, forming oxide of zinc, which is immediately dissolved in the sulphuric acid, so as to expose to the water a new surface of metal. The fact has been clearly ascertained, that by this chemical action between the zinc and the liquid, the electrical equilibrium is disturbed; part of the natural electricity of the zinc passes to the water; in which it goes on accumulating until it arrives at its maximum tension, having no means of escape, but having at the same time a constant tendency by its accumulation in the fluid to check the chemical action. If, now, the two plates be inclined, so as to touch each other, as shown in Fig. 410, where C represents the copper, and Z the zinc plate, the chemical action will be found to proceed more rapidly—a fact explained by the circumstance, that the negative metal, copper, is thus brought into communication with the positive metal, zinc, so that the electricity which passed from the zinc to the liquid, now escapes from the liquid to the copper, and back again to the zinc at the point of contact between the metals, thus keeping up a constant current of electricity so long as the chemical action proceeds. In this case, also, after the contact is effected, the hydrogen gas, instead of being disengaged as formerly from the zinc plate, is found to be extricated at the copper surface. The copper being negative to the zinc, attracts the positive hydrogen, while the negative oxygen of the water combines with the zinc, forming an oxide of that metal, which, as already stated, is dissolved by the sulphuric acid.

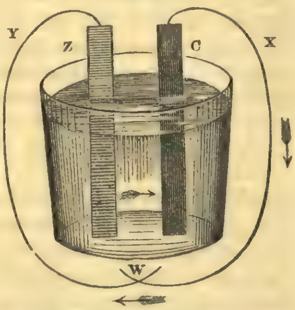
Fig. 410.



This experiment illustrates what is termed a *simple galvanic circle*, and the liquid in this case corresponds to the fluids in those parts of the leg of the frog that are brought into contact with the metals in Galvani's experiment. The action in both cases is the same. The liquid or fluid operates on the more oxidizable metal, which imparts to the former a portion of its electricity, and this is conveyed round in a circle by the other metal.

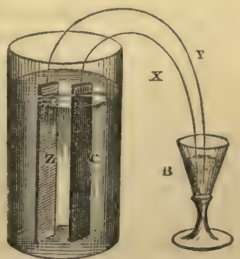
It has been assumed in the experiment above-mentioned, that, to complete the galvanic circle, the zinc and copper plates are brought into actual contact. This, however, is not necessary; any communication established between them by means of some conducting medium is quite sufficient. This communication may be effected by wires extending from the one to the other, as shown in Fig. 411. These wires may be of any metal, but copper being one of the best conductors, is usually employed for this purpose. The circuit is lengthened by this means, but the chemical action and the course of the electricity continue the same. The latter, as shown by the arrows, passes from the zinc to the liquid, through which it is communicated to the copper, and thence by the wires X and Y, which are supposed to be placed in contact at W, it returns to the zinc plate, Z.

Fig. 411.



This is still a simple galvanic circle. The wires have no action, except as conductors of the electric fluid. They admit also of directing the electric current through such bodies as it may be desired to subject to its operation, or of interrupting or renewing at pleasure the communication between the metallic plates, supposing the latter to be fixed in a frame, as in other forms of the apparatus to be noticed afterwards. For example, by disconnecting the wires at W—Fig. 411—the current ceases, or by introducing the ends of the wires into a fluid in the glass, B—Fig. 412—without bringing them into actual contact, the electricity will pass through the fluid from the wire, X, to the wire, Y, and thus the circle will be completed. When the action is sufficiently powerful, certain fluids, such as sulphate of copper, may thus be subjected to decomposition, and hence, in this case, the

Fig. 412.



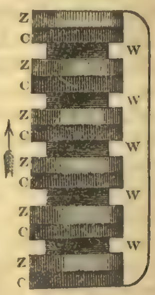
glass, B, is termed the *decomposition cell.* This is, in fact, a miniature form of the simple apparatus now usually employed in electro-metallurgical operations on the large scale. If the plates are of small size, the amount of electricity developed by this simple arrangement is very small; but by enlarging the size of the plates and increasing their number, as will be afterwards explained, their power may be indefinitely increased. A very large battery of this description, consisting of sheets of zinc and of copper, formed into coils, so as to encircle each other, and separated only by interstices of a quarter of an inch in width, was constructed by Dr. HARE, Professor of Chemistry in the University of Philadelphia, and which, from its remarkable power of producing heat, was termed by him a *calorimotor.* Mr. PEPYS constructed another for the London Institution, which consisted of only two plates, zinc and copper, coiled round a cylinder of wood, and prevented from coming into contact by ropes of horse-hair, which is a non-conducting substance. The metallic sheets thus coiled were each sixty feet long by two wide; and the whole was suspended over a tub of acid, so that by a pulley it could be immersed and removed.

Quantity and Intensity of Electricity.—Although, however, by enlarging the plates to any required superficial extent, the *quantity* of electricity developed by a simple galvanic circle may be proportionally increased, yet it is important to remark, that there are certain effects, requiring *intensity* of galvanic action, which cannot be produced by a battery of this description composed of a single pair of plates. The reader's attention is particularly requested to this distinction between electricity of *tension*, on the one hand, or electricity accumulated upon surfaces, and manifesting itself by attractions and repulsions, and by discharges passing through the air—and, on the other hand, electricity in *motion*, which manifests itself by its heating and decomposing power. The tension, or, as it is commonly termed, the intensity of the electricity produced by a simple galvanic circle, however large the superficial extent of the plates, is very trifling. It has little tendency to escape or to force its way through badly-conducting substances, such as air, or even pure water, or the resistance offered by a great extent of wire. At the same time its quantity may be great, and, if made to traverse a very fine metallic wire, the heat will be sufficient to fuse the most obdurate metals, and to exercise a most powerful decomposing effect, even when no spark can be elicited, and when the disturbance of the electric equilibrium cannot be detected by the most delicate instruments.

The quantity of the electricity put in motion by that arrangement which constitutes the simple galvanic circle, is dependent upon two circumstances—first, the size of the plates, and, secondly, the nature and strength of the interposed acid or liquid. Not only is the quantity augmented by increasing the superficial extent of the plates, but it is heightened likewise by increasing the strength of the acid up to a certain point. In the case of zinc and dilute sulphuric acid, for example, the more rapidly the zinc is oxidized by the influence of contact with the copper, and the oxide removed, so as to expose successive new surfaces to the action of the fluid, the greater is the quantity of electricity evolved. Still, so long as the arrangement is that of a simple circle, the intensity remains nearly the same; and to increase this, recourse is had to alternations of the metals and acid, which constitute a *compound galvanic circle.*

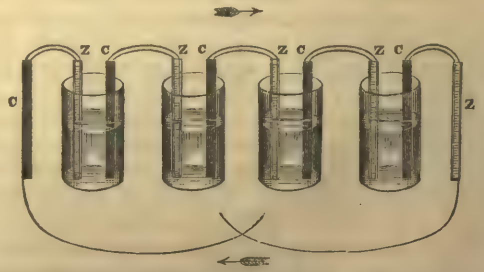
VOLTA'S PILE.—This compound arrangement introduces the *voltaic pile*, which, as already stated, constitutes in principle the common voltaic or galvanic battery. VOLTA, in prosecuting GALVANI'S experiments, discovered the principle of intensity by using a number of pairs of plates, moistened by a saline or by an acid liquid; and in 1800 he published a description of the apparatus or *pile*, which he had contrived for this purpose. It consists of a succession of pairs of plates of two dissimilar metals, such as zinc, Z, and copper, C, each pair being separated on either side from the adjacent pairs by pieces of bibulous card or of flannel, W, moistened with salt and water, or with very weak acid. VOLTA used silver instead of copper for the negative plate, and it will afterwards be shown that different metals may be employed in such combinations, though zinc and copper are generally the most convenient and economical. This apparatus was found to produce effects of a purely electrical character. On touching the ends of the pile with a finger of each hand previously moistened, an electric shock was experienced; sparks were obtained between two pieces of charcoal attached to the ends of the terminal wires; and when one of the wires was made to touch the cap of an electroscope, the gold leaves were found to diverge. In arranging the plates of the pile, a uniform order of succession must be observed. Thus, if a plate of copper, with a wire attached to it, form the bottom of the pile, a piece of wet card or flannel must be placed upon it, then zinc, then copper, then card or flannel again, and so on, terminating at top with a zinc plate, to which is attached the other end of the wire.

Fig. 413.



By bearing the above description in mind, the reader will perceive as he proceeds that this apparatus is simply a compound galvanic battery, in which the moistened pieces of card or flannel perform the part of the acid cells of the trough. VOLTA himself suggested a still

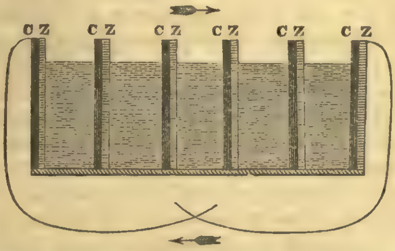
Fig. 414.



nearer approach to the latter, which he termed a *couronne de tasses*, or *crown of cups*, consisting of a series of cups or cells, containing an acid liquid, in each of which was a pair of plates of dissimilar metals, one of which, such as the zinc, was made to communicate by a wire with the copper in the adjacent cell. In this arrangement, shown in Fig. 414, the fluid in the cells performs the part of the moistened pieces of flannel, and operates with greater effect for a longer period. It is, in short, the galvanic battery in all its essential parts, and nothing remained but to give it a more convenient form, and by certain improvements of detail to economize the material.

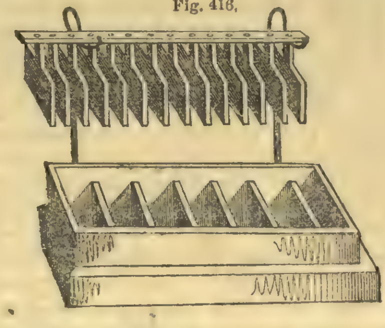
CRUIKSHANKS' BATTERY.—The first step in this direction was made by Mr. CRUIKSHANKS of Woolwich, who constructed the first *trough battery.* Adopting VOLTA'S idea, which was generally received at the time, and is still supported by the German school, namely, that the contact of dissimilar metals was the cause of the electric action which the pile exhibited, CRUIKSHANKS soldered together each pair of zinc and copper plates, with the view of insuring intimate contact between them. The plates were of a square form; and the pairs, thus soldered together, two and two, by their flat surfaces, were fixed into water-tight grooves in the sides of a trough of baked wood, at the distance of about a quarter of an inch from each other, so as to constitute water-tight partitions, dividing the trough into a series of narrow cells between every pair of plates, which were filled with a solution of chloride of sodium, or a mixture of acid and water. The plates being so arranged that all the zinc surfaces faced one end of the trough, and all the copper the other, it followed that the series was terminated at one end by a copper, and at the other by a zinc plate. These terminal plates, being brought into communication with each other by copper or silver wires, completed the circuit, as shown in Fig. 415, which is a sectional view of the apparatus.

Fig. 415.



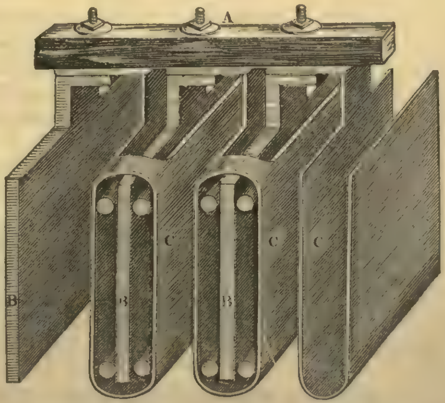
BABINGTON'S BATTERY.—In point of compactness, CRUICKSHANKS' battery was a very considerable improvement on the *couronne de tasses*; but still it was attended with great practical inconveniences, arising from the difficulty of cleaning or renewing the plates, the necessity of pouring out the fluid to arrest the chemical action, and other causes. A modification, suggested by Mr. BABINGTON, obviated these disadvantages. In this arrangement—Fig. 416—the trough, which may be of wood or earthenware, is divided by a series of partitions of the same material, into as many compartments as there are pairs of plates to be used. The zinc and copper plates are united in pairs, as in CRUIKSHANKS' battery; but instead of being soldered together by their flat surfaces, each of the pairs is united at one point only by a slip of metal passing from the one and soldered to the other, so that when the connecting slip is bent round in a U form, the faces of the plates are parallel to each other, but do not touch. The plates are connected together by a slip of baked wood, and are so arranged that when let down into the trough, a zinc and a copper plate of each adjoining pair pass into the same cell. By this arrangement, the plates and the fluid being independent of each other, the former may be taken out and readily cleaned, or replaced when injured, without disturbing the fluid; and the latter may, in like manner, be removed and changed, or the action may be suddenly arrested by merely raising the plates.

Fig. 416.



WOLLASTON'S BATTERY.—The last improvement on the common galvanic battery which it is important to mention, as having in fact given it the form now most generally in use for electro-metallurgical operations, was suggested, in 1815, by Dr. WOLLASTON, who found that the power of a battery was much increased, and a great economy in the quantity and wear of the zinc was effected, when both surfaces of each plate of zinc were opposed to a surface of copper. To effect this, the copper plate, C, was extended and bent round, so as to encompass the plate of zinc, Z, as shown in Fig. 417, while a slip of the copper at one side was connected with the zinc plate in the adjoining cell.

Fig. 417.



Battery now used.—The form of battery now in general use for electro-metallurgical operations on the large scale, is exactly **WOLLASTON'S** in principle, but with a slight modification upon the original construction in the manner of adjusting the bent copper plates. By the arrangement represented above, when amalgamated zincs are used—as will be explained afterwards—small quantities of the amalgam of zinc fall from the zinc upon the copper, which interfere with the action of the battery by forming a new amalgam with the copper plates, thus causing a considerable loss of electrical power, and also of copper and mercury. To prevent this, the double copper plate, *a a*—Fig. 418—is now inverted, so as to be open below, while the neck or connecting bend, *b*, is above the zinc, and the part, *c*, is bent back, and fixed by a binding screw to the zinc in the next cell. This arrangement is shown in Fig. 419, where P P denotes the partitions of the trough; Z, the zincs; C, the bent copper plates; and *w w* the wires attached to the copper plate at the one end, and to the zinc plate at the other.

Fig. 418.

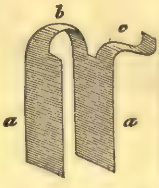
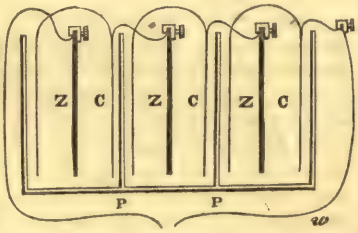


Fig. 419.



Although the common trough battery, constructed on **WOLLASTON'S** plan, with the modification just mentioned, appears to admit of no essential improvement, yet it is attended with certain defects which seem to be inseparable from all batteries composed of similar materials. In the first place, assuming that these are zinc, copper, and dilute acid, the water of the latter can only dissolve a given quantity of sulphate of zinc, acting most freely at first, and therefore, as the action of the battery proceeds, the solvent power of the water decreases and affects the action of the battery. Secondly, a portion of the sulphate of zinc, which is being continually formed, is occasionally reduced upon the surface of the copper, thereby weakening the electric current, both by inducing a *local* galvanic action at the copper surface, and by tending to send a current of electricity in an opposite direction to the main current. In the third place, the copper becomes covered over with oxide and other impurities, which impair the action, unless the plates are frequently cleaned, which causes annoyance and interruption; and, fourthly, the hydrogen evolved at the copper plate adheres with considerable force to the surface of that metal, so as to prevent its direct and continuous contact with the fluid, and thus to produce the effect of a proportional diminution of surface.

It was to obviate these disadvantages that **DANIELL** invented his *constant battery*, which, although attended with some inconveniences peculiar to itself, and not now generally employed in electro-metallurgical operations on the large scale, will ever be regarded with peculiar interest, *as having been the means of leading directly to the discovery of the art of depositing metals by electricity.* It is also peculiarly fitted for operating on the small scale, and as such it will always be a favorite with the amateur. An accurate description of this battery involves a complete elucidation of the principles of the electrotype, and therefore it must be given minutely; but before proceeding to do so, there are some collateral points of importance connected with galvanic action and galvanic batteries in general, which have been hitherto omitted to preserve the continuity of the narrative, but which it will now be desirable to introduce to the reader.

POSITIVE AND NEGATIVE RELATIONS OF THE METALS.—It has been remarked, in a preceding part of this article, that, to excite a galvanic current, two dissimilar metals must be brought into contact or communication with each other, and also with a fluid which acts more powerfully on one of the metals than on the other. Dilute sulphuric acid is the fluid, and zinc and copper are the metals, which have been hitherto selected as the types of this galvanic combination. These are the substances in common use, having been generally found the most convenient in point of economy and otherwise; but other metals and other fluids may be used, and are actually employed with advantage in certain forms of battery. In the zinc and copper combination, it has been remarked that the zinc is the metal on which the most powerful chemical action is exerted; indeed, when the metals are brought into communication, the whole of the action is found to be exerted on the zinc, and the copper is entirely inert, except as a conductor of the electricity, which passes from the zinc to the fluid, and thence through the copper back to the zinc. In this, or any similar combination, the metal which undergoes solution, such as the zinc, and from which the electric current proceeds, is termed the electro-positive metal; the other, which remains passive, or by which the electric current is simply conducted back to its source, is termed the electro-negative metal. These expressions are merely relative, not absolute; zinc is positive in this sense with regard to copper, but negative with regard to potassium; and generally, when acids and other fluids of an oxidating nature are employed, every oxidizable metal is positive with regard to a metal which is oxidizable in a less degree. Keeping this in view, the following is the relative order of the common metals in respect of their electro-positive and electro-negative properties, when immersed in water acidulated with sulphuric or hydrochloric acid—the metal relatively most positive standing first, and the most negative last—

Most positive.
1. Potassium.
2. Zinc.
3. Cadmium.
4. Tin.
5. Iron.
6. Lead.
7. Copper.
8. Bismuth.
9. Nickel.
10. Silver.
11. Antimony.
12. Gold.
13. Platinum.

Most negative.

Now, it will be seen that, as in any galvanic arrangement, each of the above metals is positive to all those that follow it in the list, any one of them, such as zinc, will be more positive to one that is separated by a wide interval, such as platinum, than to one that is nearer to it, such as copper or iron. Zinc and platinum will therefore make a stronger battery than zinc and copper; the latter will be more powerful than a battery with zinc and iron; and zinc and tin will furnish a very weak battery.

It is to be observed, however, that the order in the above list is not constant with all fluids, with all acids, or even with the same acid at different degrees of concentration. For example, in strong nitric acid, iron is nearly as electro-negative as platinum. When alkaline solutions are employed, the order is found to be nearly the same as that above given; but iron is again an exception, and occupies, in that case, a place intermediate between copper and silver.

The temperature has also a remarkable influence. Mr. GORE observed, for example, that tin is negative to iron at all temperatures between 62° and 203° Fahr. in distilled water, and positive to it at 212°; it is positive to iron at all temperatures between 62° and 212° in a saturated aqueous solution of boracic acid; also the same to iron between those temperatures in a strong solution of phosphoric acid in distilled water; or in one measure of sulphuric acid mixed either with nine or ninety-six measures of distilled water; or in a mixture of one measure of the same acid, and one hundred and ninety-two measures of distilled water from 73° to 158° Fahr., and negative to iron above that to 212°; it is positive to iron from 72° to 212°, in a mixture of equal measures of hydrochloric acid and water; it is negative to iron from 70° to 77°, and positive above that to 212° Fahr. in one measure of hydrochloric acid and nine measures of distilled water; it is negative to iron from 70° to 212° in one measure of hydrochloric acid and ninety measures of distilled water, and positive to iron from 68° to 212°, in one measure of hydrofluoric acid and nine measures of water; it is positive to iron in one measure of nitric acid and nine measures of water from 70° to 111°, and negative from 111° to 212°; and it is positive to iron from 82° to 212° in a mixture of one measure of nitric acid and ninety-six measures of water.

The same skilful electro-metallurgist remarked that iron is electro-negative to copper in the following liquids:—powerfully in a solution of sulphide of ammonium; feebly in a saturated aqueous solution of acetate of ammonia; in an aqueous solution of ammonite of copper, and increased by heating the liquid; in liquid ammonia, or in a saturated aqueous solution of ferrocyanide of potassium—each but for a short time—it then becomes positive; in a saturated aqueous solution of bichromate of potassa; in a strong aqueous solution of sulphide of potassium, becoming increasingly positive up to the boiling point of the liquid; lastly, in a saturated aqueous solution of hyposulphite of soda. Iron is negative to brass in a strong solution of sulphide of potassium, increasingly up to the boiling point.

These observations are interesting, and call for further investigation.

RELATIVE CONDUCTING POWER OF METALS.—On the whole, the preceding tabulated order of the positive and negative relation of the metals may be considered as constant with reference to the fluids that are generally used in galvanic batteries; but still, there are other considerations which must be taken into account in estimating the relative practical value of the metals for galvanic purposes. The most important of these is the power of freely conducting an electric current—a property in which lead, for example, is found to be very deficient. The relative efficiency of some of the metals in this respect, that is to say, their respective conducting power, is shown by the following numbers:—

Silver,	120	Platinum,	24
Copper,	120	Iron,	24
Gold,	80	Tin,	20
Zinc,	40	Lead,	12

It thus appears that, in respect of conducting power, lead stands at the very foot of the scale; it is also deficient in another important property, that of keeping a bright surface, and not becoming oxidized, the oxide destroying its conducting power; otherwise its mere position in the positive and negative scale would point it out as a cheap and efficient substitute for copper to form the negative plate. Zinc and platinum, according to the same scale, would constitute the best arrangement of all; and is indeed used with enormous effect in a battery which will be described afterwards; but while, on the one hand, the great expense of the platinum places it beyond general reach for common purposes, it will be observed that, on the other hand, copper has a marked superiority in conducting power. Silver is equal to copper in the latter property, and still more negative with regard to zinc; but, on the whole, zinc and copper are found to combine the advantage of economy with efficiency, in such a manner as to give them a decided preference for use in the common battery.

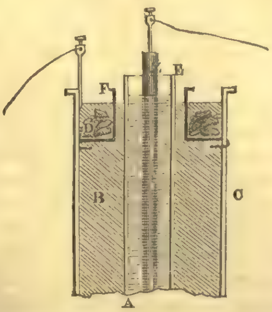
AMALGAMATION OF THE ZINC.—Whatever metal may be used for the negative plate, zinc is uniformly employed for the positive; and here it is important to observe, that an immense advantage is gained by previously forming the surfaces of both sides of the zinc into an amalgam with mercury. When a plate of the ordinary zinc of commerce is immersed in dilute sulphuric acid, the zinc is rapidly dissolved, and hydrogen gas is evolved in great quantity. But if the surface of the zinc, after being cleansed by immersion in the acid, be rubbed over with mercury, a brilliant amalgam is speedily formed over the whole face of the plate; and then it may be plunged into the acid without undergoing any chemical change for hours, so long as the galvanic circuit is not completed by bringing the zinc into contact or metallic communication with the negative plate. On the other hand, if this communication be established, the chemical action will proceed, and the amalgamated zinc will be dissolved, but much more slowly than before, and yet with a more abundant development of the electric current. It is therefore found highly conducive both to economy of material, and efficiency and constancy of operation, to amalgamate the zinc plates employed; and this is uniformly practised.

How it happens that the zinc when amalgamated does not lose in efficiency as much as it gains in durability, is not exactly understood; but it is attributed partly to the absence of what is termed *local action.*

The impurities of the zinc of commerce, containing an admixture of lead and other metals, positive or negative to each other, will naturally create conflicting currents, acting like an infinite number of small batteries, and these will proportionally diminish the main current of the battery. This explanation may be given as a definition of what is expressed by local action, which it is always an object of great importance to avoid. This may be accomplished to a certain extent by employing zinc perfectly pure; but such zinc cannot be procured without great difficulty; and the amalgamated zinc is not only prepared with facility, but is acknowledged on all sides to constitute the most efficient material that can be employed for the purpose. The best kind of zinc for the battery is that *milled* or *rolled* into plates, which should not be thinner than one-eighth of an inch; and if their size be upwards of four inches square, the best thickness is one-fourth of an inch. Cast plates of zinc are so porous, that no amalgamation will protect them from local action; they are also negative to rolled zinc, and are, consequently, less effective in developing the electric current.

DANIELL'S CONSTANT BATTERY.—The disadvantages previously mentioned, as belonging to all the forms of the common battery, and producing inconstancy of action, or a gradual decrease of power, in consequence of adhering hydrogen or a deposit of oxide, upon the negative plate, were overcome by Professor DANIELL, who published in 1836 an account of his *constant battery*. This battery, which is shown in section in Fig. 420, consists of an exterior vessel of copper, C, in which is placed a smaller vessel of porous earthenware or unglazed porcelain, E. Within the porous cylinder is suspended a cylindrical rod of amalgamated zinc, resting upon the rim of the porous vessel by a slip of wood passed through the upper part of the zinc rod. Binding screws are attached to the copper vessel and the zinc, and by means of a wire or slip of copper, a metallic communication is thus established between them.

Fig. 420.



To put this battery in operation, the porous vessel, E, is filled with an acid solution, A, consisting of one part sulphuric acid diluted with seven parts of water; and the space between this and the copper cylinder is filled to the same height with a solution of sulphate of copper, B, acidulated with one-eighth of its bulk of sulphuric acid. The solution is kept saturated with the salt by means of crystals of the sulphate, D, which rest upon the perforated shelf, F.

The action in this case is as follows:—The acidulated fluid in the porous vessel acts upon the zinc, as in the common battery, producing an evolution of electricity, which is conveyed through the porous vessel, as if no such obstacle intervened; but, at the same time, the sulphate of zinc which is formed in that vessel is prevented from mixing with the copper solution in the outer vessel. The electric current, in passing through the sulphate of copper, decomposes that salt, and instead of hydrogen being liberated from the surface of the copper, as in the common battery, it combines with the oxygen of the copper in the sulphate of copper, by which the copper is reduced in the metallic state upon the surface of the cylinder of that metal forming the outer vessel. Another advantage of this battery is, that the sulphate of copper has no tendency to act upon the copper itself, and thus to produce a counter-current. Accordingly, this arrangement was found to keep up a current of uniform strength for many hours, and to furnish electrical science with a battery of far greater power for its size than any which had previously been used.

The circumstance connected with this battery which led, by an almost necessary consequence, to the discovery of electro-metallurgy, is the action just referred to, namely, the constant deposition of the reduced metal from the sulphate upon the copper plate.

Any number of cells on this principle can be arranged and connected so as to form a battery of great power. Fig. 421 shows a convenient form of the copper plates, consisting merely of rectangular sheets of copper, *a*, bent into a cylindrical shape; and these, instead of being formed into vessels, may be inserted in glass or earthenware jars for holding the sulphate of copper. By means of the strip, *b*, each plate is easily connected with the zinc rod of the adjacent cell. The colander for supporting the crystals of the sulphate to keep the fluid in a state of saturation, rests upon little pieces or pins of copper which are made to project inwards upon the sheet, at a suitable height, as at *c*. Fig. 422 shows the manner in which a number of these cells may be arranged and connected in a consecutive series.

Fig. 421.

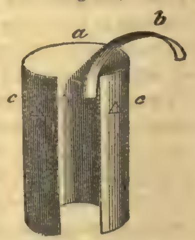
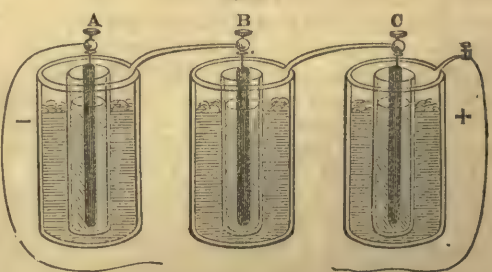
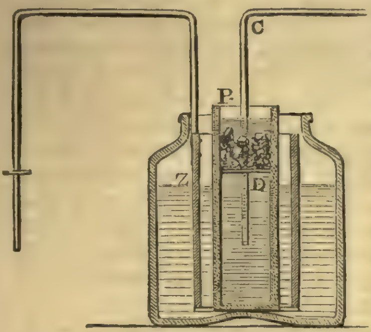


Fig. 422.



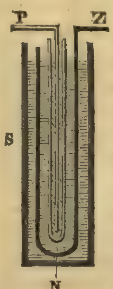
The relative position of the zinc and copper in this battery is evidently not essential, provided they are separated by the porous vessel, and each is immersed in its own proper liquid. Thus, in the arrangement represented in Fig. 423, which indicates the cell of a Daniell battery much employed for working the French telegraphs, Z is a cylinder of zinc, surrounding the porous vessel, N; within the latter is a copper diaphragm, D, charged with crystals of sulphate of copper; and the liquid external to the porous vessel is dilute acid. In this case the diaphragm, D, and a portion of the wire, C, act as the negative plate.

Fig. 423.



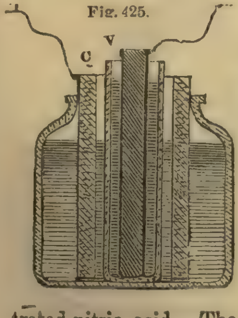
Grove's Battery.—Adopting the porous cell, but employing nitric acid instead of the copper salt, and platinum instead of copper, Grove constructed a battery of still greater power, although upon the same principle. In this battery the outer vessel, S—Fig. 424—is of glass or earthenware, in which is suspended a porous vessel, N, as in Daniell's. But instead of a rod of zinc, a slip of platinum, P, is inserted in the porous tube, which is nearly filled with *undiluted* nitric acid. The zinc, Z, in the form of a flat slip or sheet, bent, as shown in the figure, so as to infold the porous tube, is placed in the outer vessel, which is filled with sulphuric acid, diluted with ten parts of water. As platinum is the least liable of the metals to chemical action, and zinc is one of the most readily attacked by acids, while nitric acid absorbs with ease the hydrogen liberated at the platinum, and the resulting liquid is one of the most perfect fluid conductors, the action of this battery, when first excited, is very energetic in proportion to its size. It is the most powerful of all batteries, but is not so constant as Daniell's, and is not so well adapted for electro-metallurgical operations, in which intensity of action is much less important than constancy and quantity.

Fig. 424.



Bunsen's Battery.—This is simply a modification of Grove's, in which, with a view to economy, the platinum element is replaced by the cheaper material, charcoal. A solid cylindrical rod of this substance, made from the residuum taken from the retorts of gas-works, is placed in the porous vessel in contact with the nitric acid, instead of the slip or rod of platinum. Sometimes the carbon is in the form of a hollow cylinder, and is made by coking pounded coal in a proper iron mould. This arrangement is shown in Fig. 425, where Z is the zinc rod inserted in the porous vessel, V, containing dilute sulphuric acid, and C is the hollow cylinder of carbon immersed in concentrated nitric acid. The real Bunsen battery, however, is made by employing the coke vessel itself as the porous cell; and the arrangement in that case may be conceived by supposing the zinc rod, Z, to be removed, and that V represents the vessel of coke or carbon filled with nitric acid and sand, while in the place of C is a sheet of zinc bent into a cylindrical form, so as to surround the porous coke vessel, external to which is dilute sulphuric acid. By soaking the coke in sugar, and calcining a second time, great compactness is given to the rod or cylinder. This battery, when properly constructed, is not less efficient than Grove's, and is much used on the Continent and in America for working the electric telegraphs; but it is seldom employed for electro-metallurgical purposes.

Fig. 425.



Callan's or the Maynooth battery is another interesting modification of Grove's. Taking advantage of the remarkable passativity of cast-iron, in relation to a mixture of strong nitric and sulphuric acids, Professor Callan constructed his apparatus with cast-iron cells, in which a porous porcelain cell with a zinc plate is inserted. The latter contains dilute sulphuric acid; the former a mixture of the two acids just mentioned. This is a powerful galvanic apparatus, and the original cost is very small.

Smee's Battery.—It has been shown that one of the principal disadvantages connected with the common battery, is the obstruction occasioned by the hydrogen adhering to the negative plate. This is overcome in the Daniell and Grove batteries by chemical agency; in the former the sulphate of copper, and in the latter the nitric acid employed, absorb the hydrogen. Another method of effecting the same object, *by mechanical means*, was discovered by Mr. Alfred Smee, surgeon to the Bank of England, and the battery contrived by him on this principle is much employed by amateurs in electro-metallurgical processes. Smee observed that, though the hydrogen escaped with difficulty from smooth surfaces, it passed off much more freely when the copper plate of the common battery was roughened, either by corrosive acids, or by rubbing the surface with sand paper. Availing himself of this property of rough surfaces, Mr. Smee employs, as the negative plate of his battery, a plate of silver, the faces of which have been roughened by the deposition of finely-divided platinum upon its surface. The platinum may either be deposited by electro-chemical agency, after brushing over the silver with strong nitric acid, and then washing it, when, if it be placed in a vessel containing dilute sulphuric acid, to which a few drops of bichloride of platinum have been added, the latter metal will be thrown down in a pulverulent form; or the silver may be merely well roughened with sand paper, and then inserted in the platinum solution made very hot, when a similar deposit will be obtained.

Having thus roughened the surface of the silver with the platinum powder, Mr. Smee, in arranging the plates, reverses the order of Wollaston's battery, surrounding the more expensive silver with the positive zinc, so as to present a surface of zinc to each face of the platinized silver. The liquid employed is dilute sulphuric acid. Fig. 426 represents a battery constructed upon Smee's principle, and Fig. 427 shows the plates detached. S, in the latter figure, is a thin platinized silver plate, supported in a light frame of wood; to the upper part of this frame a binding screw in metallic connection with the silver, is fastened for the purpose of connecting the plate with the zincs of the adjoining cell, by means of a strip of sheet copper bent, as at C. Z, Z, are similar sheets of amalgamated zinc, which are supported on either side of the silver plate by a clamp, B, and are prevented from contact with it by the wooden frame; they are brought into metallic connection with the silver of the adjacent cell by a second binding screw in the clamp shown at B. The series of plates, thus arranged, are attached to a wooden frame, and being counterpoised by weights, as shown in the figure, or fitted, as in Ackland's improved construction of this battery, with an iron rod and ratchet-wheel, can be readily elevated or depressed, so that the plates may be either partially or entirely immersed in the liquid, or altogether raised out of it when not required to be in action.

Fig. 426.

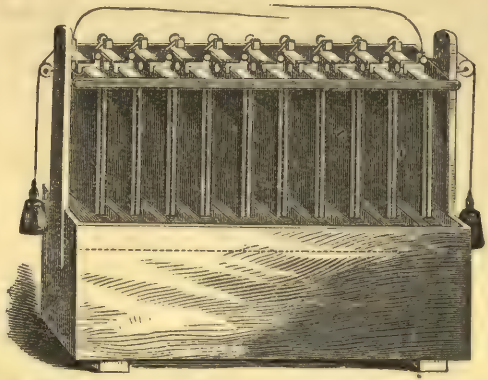
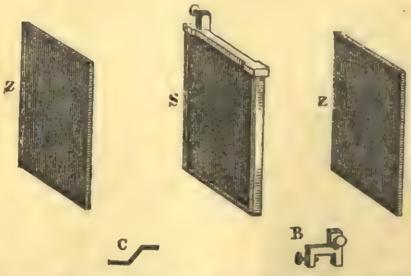


Fig. 427.



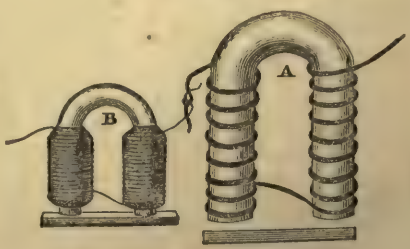
The Magneto-Electric Machine.—Instead of voltaic batteries to supply the electric current to the metallic solutions, magneto-electric machines have been employed, and for various modifications of these several patents have been obtained. They are sometimes improperly termed electro-magnetic machines, from which, however, they differ as widely as magneto-electricity differs from electro-magnetism. The latter is magnetism derived from electricity; the former is electricity derived from magnetism; and this is the principle of the magneto-electric machine. It may be regarded, indeed, as a kind of battery; and having been employed in that capacity, both for electro-metallurgical purposes, and in working the magnetic telegraph, some account of the principle of its action seems to be a necessary appendage to the history of the various modifications of the galvanic or voltaic battery.

When Oërsted, in 1819, discovered the connection between electricity and magnetism, by observing that a magnetic needle, freely suspended, was deflected at right angles to an electric current passing near it, the attention of philosophers was powerfully drawn to the subject, and Ampère, in 1820, found that a bar of soft iron placed within a coil of copper wire, through which a current was transmitted from a voltaic battery, became magnetic, maintaining its magnetism so long as the current continued. If the bar, A or B—Fig. 428—is bent into the form of a horse-shoe, and the copper wire, covered with silk thread, or some other non-conducting substance, is coiled round each of its arms in the manner shown in the figure, a powerful temporary magnet will be formed by connecting the ends of the wire with the poles of the battery. In proportion to the power of the battery and the number of coils of the insulated wire, will be the degree of magnetism imparted. The magnetic power to be obtained in this manner with soft iron very far exceeds what can be permanently imparted to steel. An electro-magnet constructed by Mr. Joule was shown in the Great Exhibition, capable of lifting a ton weight; and electro-magnets of larger size have been made that lifted several tons.

It occurred to Faraday, that if magnetism was thus produced by a current of electricity, a current of electricity might be produced by magnetism, and accordingly he found that when a powerful magnet, instead of the bar of soft iron, was introduced into a coil of copper wire, the ends of which were connected with a galvanometer, a momentary current was indicated in the wire; and again, on withdrawing the magnetic bar, another momentary current in the opposite direction. When the bar was at rest within the coil there was no current. Its sudden introduction or removal was, however, clearly productive of certain electrical effects, to which Faraday gave the appropriate name of magneto-electricity.

The scientific world was thus furnished with a new source of electricity, differing as much from the common electric machine, in which the development of the fluid is produced by friction, as it differs from the galvanic battery, in which the current is produced by chemical decomposition. This new source was magnetism; but to render the discovery available for any useful purpose, it was necessary to devise an arrangement by which a steady and continuous current, or something equivalent,

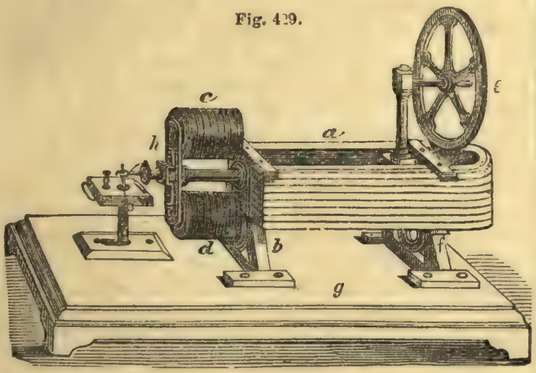
Fig. 428.



could be obtained, instead of successive momentary currents in opposite directions to each other.

The magneto-electric machine, in its most improved form, accomplishes this desirable object as nearly as possible. The essential parts and the general construction of this machine are shown in Fig. 429, where *a* is a compound permanent steel magnet, which acts in this case as the battery, or source of electric power. It is composed of several thin plates of steel, all of the same horse-shoe form, and separately magnetized and bound together—an arrangement which, by exposing a larger surface, is found to produce a much more powerful instrument than if the same quantity of steel were made into a solid magnet of the same form. This powerful magnetic battery is firmly fixed in a horizontal position on the supports, *b*, *f*, which are bolted into the stand or table, *g*. Within the coils of copper wire, *c*, *d*, which constitute indeed one continuous coil in two parts, are bars or rods of soft iron, which are formed into a kind of horse-shoe by the connecting piece, *h*, also of soft iron. The part, *c h d*, may therefore be regarded as representing a horse-shoe of soft iron, with numerous convolutions of the same copper wire round its two arms; and to send successive currents of electricity through this wire, supposing its two ends to be connected, it will only be necessary to magnetize and demagnetize alternately the core of soft iron within it, the same effect being thereby produced as if a permanent horse-shoe magnet were alternately introduced into the coil and withdrawn successively, as in FARADAY'S experiment above-mentioned. With this view the armature, *h*, is fixed on a spindle passing through the axis of the compound magnet, and connected with a small grooved wheel or pulley near *f*, which is worked by a cord or band over the larger wheel, *e*. By turning this large wheel, either by the hand or by any convenient power, the armature, *h*, may be made to revolve rapidly, and thus the cores of soft iron enclosed in the coils, *c*, *d*, are brought successively over against the two poles of the compound magnet, *a*, to which they are placed as near as possible without touching. It is well known that a piece of soft iron placed in the immediate vicinity of one of the poles of a magnet, becomes magnetic by induction, and each time, therefore, that the cores, *c*, *d*, pass in their revolution the poles of the magnet, *a*, they are strongly magnetized, whereas, when they return to the position shown in the figure, they lose their magnetism entirely.

Fig. 429.



Successive currents of electricity, alternately in opposite directions, are thus made to circulate through the coils, *c*, *d*; but it still remains to procure a current, or currents, as nearly as possible continuous in the same direction. To enter into the minutiæ of the different arrangements for this purpose, would not be consistent with the limits of this work; but it may be stated that there are two methods of doing so—either by suddenly breaking the circuit at the moment when the current has been established in one direction, and closing it again at that point of the revolution when the same current is resumed, or by making arrangements to reverse the polar relations of *c*, *d*, at the instant when the current is about to be reversed, and thus obtaining a rapid succession of currents or impulses in the same direction. The reader will readily conceive how this may be effected, either by connecting one end of the wire with a cup of mercury, into which the end of the wire from the other coil, connected with a metallic disc at the end of the spindle, as shown in the figure, dips during part of the revolution, so as to complete the circuit at certain regular intervals; or by connecting one end of the wire with springs pressing on interrupted collars of metal to which the other end is attached; and in that case either the spring or collar may be made to revolve, so as to complete and break the circuit alternately, or reverse the poles at pleasure.

It is not possible by this means to obtain a continuous current of electricity, as from the galvanic battery, but the impulses may be made to succeed each other so rapidly in the same direction, that an equivalent effect is produced for most practical purposes. To render the succession of impulses still more rapid, a number of compound magnets, with a corresponding number of armatures, may be employed. A compound machine of this kind, for which a patent was sealed in 1851, is erected at Messrs. ELKINGTON and MASON'S, and is represented in the annexed drawings—Figs. 430, 431, 432, and 433. In this machine, the iron frame, A A—Fig. 433—supports no less than eight permanent compound steel magnets, B B, which are either insulated from the frame, or placed at such a distance from it as to be perfectly free from its influence. One of the magnets, as detached, is shown in Fig. 021; it consists of eight plates of a U form, each weighing about thirty pounds. When arranged in the frame, the North poles are all placed on one side, and the South poles on the other.

There are sixteen armatures of soft iron, C C, four of which only are seen in the elevation, each weighing about fifteen pounds, and coiled round with sixty feet of insulated copper wire. One end of this wire is connected with the break-piece, D, on one side of the machine; while the other end is in contact, on the other side, with a small solid brass wheel, which, with the centre wheel, H,—to which the armatures are attached—is caused to revolve on the shaft, F, by means of a band, I, communicating with the shaft of the steam-engine. The armatures pass, in their revolutions, between the poles of the magnets, and as nearly as possible to each, so as not actually to touch them. Wires of copper which convey the current to the vats are represented by G.

The arrangement of the armatures and magnets is shown more in detail in Figs. 431 and 432, the former being a vertical section and the latter a plan of the centre wheel, with the armatures and magnets only.

The induction of electricity by magnetism alone seems at first sight to open an exhaustless source for the supply of electric agency without the trouble, the annoyance, and the cost of voltaic batteries; but hitherto it has not been of much avail. Where steam power is wanting, the labor of turning the wheel for the rapid rotation of the armatures, and even where steam is available, the irregularity and impulsive character of the current produced, are serious drawbacks to the use of magneto-electric machines as the generators of electricity for chemical operations requiring steady action. As an economical means of exciting electricity for electro-plating and gilding, it was at one time thought to promise great advantage; but even with steam power at command, and a truly magnificent machine constructed upon the best principles, Messrs. **ELKINGTON** and **MASON** have not found it to answer so well as voltaic electricity, in consequence of the want of continuity and steadiness in the current. A similar machine has been applied, however, to work the needle telegraph with very good effect.

Fig. 430.

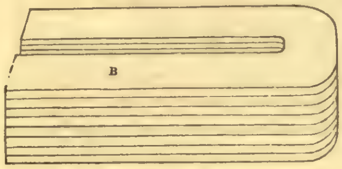
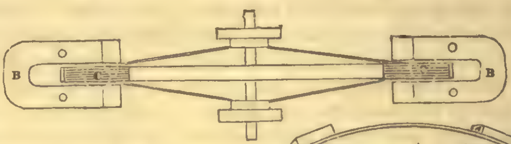


Fig. 431.



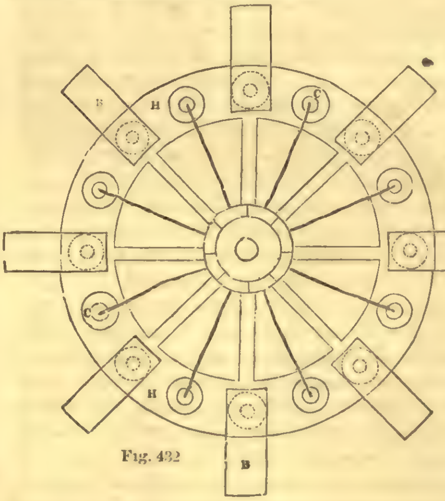


Fig. 432

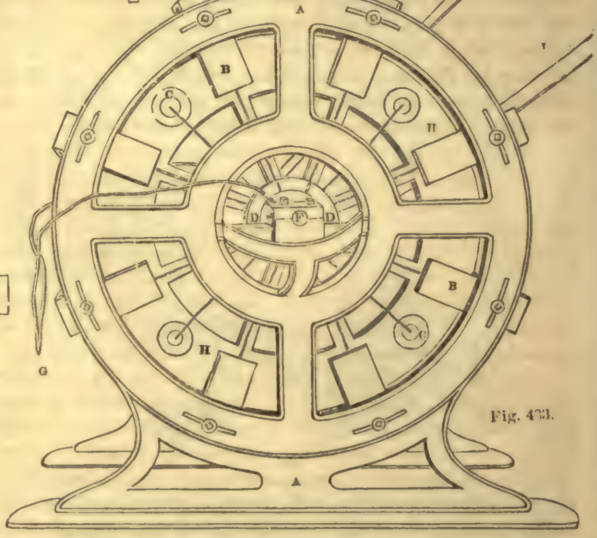


Fig. 433.

Definitions of Terms.—There are one or two terms employed to designate the different parts and materials of galvanic batteries, which may be occasionally used in connection with their application in the subsequent portion of this article, and which it will therefore be useful to define before proceeding to the practical details of the subject. The two extreme plates of a battery or voltaic pile, or the ends of the wires proceeding from these extreme plates, and immersed in a fluid or connected with any other substance through which the electric current passes from the one to the other so as to complete the circuit, are termed the *poles* or *electrodes* of the battery. The positive pole or electrode is that from which the electricity proceeds, and is termed the *anode;* the negative pole, or that which receives the electricity, is termed the *cathode.* Thus, when the two extreme plates of a battery are brought into direct metallic communication, the zinc plate is the positive pole, or anode, because it is considered as the source from which the electricity proceeds through the fluid to the negative copper plate or cathode. But when the wire connecting the two plates is broken, and its ends immersed in a fluid, in that case the end of the wire connected with the copper plate becomes the anode or positive pole, and the end of the other wire the cathode or negative pole, because the electric current, considered with reference to the fluid interposed at the breach of the wires, now proceeds from the copper, and passes back to the zinc. The fluid, such as sulphate of copper, which undergoes decomposition, by the electric current passing through it, is termed the *electrolyte;* the action is termed *electrolysis.* When this action occurs, the metal is deposited upon the cathode or negative plate, and the oxygen is liberated at the anode or positive plate, which is dissolved in the fluid. Numerous equivalent terms have been invented, with which it is perhaps unnecessary to perplex the reader.

DISCOVERY OF ELECTRO-METALLURGY.—It has been stated that Professor **DANIELL**, in using his constant battery, observed the deposition of metallic copper upon the negative surface; and, subsequently, De La Rue, experimenting with the same form of battery, not only found the copper plate covered with a coating of metallic copper, but further observed that the sheet of copper thus formed, having been stripped off, exhibited the counterparts of every scratch of the plate on which it had been deposited. Nay, it has been remarked that, even so early as in 1805, Brugnatelli had gilt silver medals by a similar process.

Still, the idea of applying these observations and experiments to any practical purpose, did not occur to any one in this country, so as to be publicly claimed as a new discovery, till a paragraph appeared in the *Athenæum* of 4th May, 1839, announcing that Professor Jacobi, of St. Petersburg, had discovered a method of converting any line, however fine, engraved on copper into a relief, by a galvanic process. In consequence of this announcement, Mr. Thomas Spencer, who had been privately engaged in prosecuting the same subject, gave notice to the Liverpool Polytechnic Institution, on the 8th of the same month, that he would make a communication of a process which he had discovered for effecting results similar to those of Professor Jacobi. He afterwards changed his mind, with the view of reading his paper at the approaching meeting of the British Association, to which it was communicated for that purpose; but having been overlooked by Dr. Lardner, it was omitted at the British Association, and was read for the first time at the next meeting of the Liverpool Polytechnic Institution on the 13th of September, 1839. The paper contained a minute account of experiments connected with this subject, in which Mr. Spencer stated he had been engaged from September, 1837. It appeared that, at that period, he had been induced to make some electro-chemical experiments with a constant battery of one cell, in which, instead of a copper vessel, a small piece of copper was used for the negative plate, and an equal-sized piece of zinc for the positive, the whole being placed in a glass vessel. In the course of these experiments, a piece of melted sealing-wax was accidentally dropped upon the copper plate, and having occasion to examine the plate during the progress of the experiment, he found that the whole of it was covered with deposited metallic copper, *with the exception of that portion which had been covered with the wax.* This suggested to him the idea that, by coating a copper plate with soft cement, consisting of bees'-wax and other materials, and drawing any letters or figures through this coating, so as to expose the copper at the parts required, the lines would be deposited in relief, and a kind of stereotype plate formed, from which impressions might be taken by the common process of printing. Mr. Spencer's efforts in electrotyping were chiefly directed towards this result, in which he succeeded beyond his expectations.

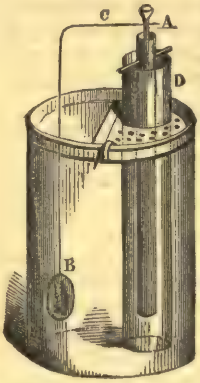
In the course of the same experiments, he afterwards hit upon the process of copying coins and medals, which, however, he considered of minor importance. This discovery he made by another accidental circumstance. When about to put the battery in operation, not having a slip of copper at hand to form the negative plate, he used, as a good substitute, a penny, which he fastened to one end of the wire, and put the other in connection with a piece of zinc. The result was, that the copper coin became covered with a deposition of copper, and in removing the wire to use it for another experiment, he pulled off a piece of the deposited copper along with it, on examining the under portion of which he found it to contain, *in intaglio*, a part of the head and letters of the coin, as smooth and sharp in every respect as the original on which it was deposited. This led him to further inquiries, and by taking impressions of coins, medals, type, and even woodcuts in sheet-lead, he finally succeeded in producing, by deposition in the battery, perfect fac-similes of them in copper, being, of course, in relief.

It so happened, that before the paper containing these details was read to the Liverpool Institution, and only a few weeks after Mr. Spencer had first given notice of his intention to read it, a letter from Mr. C. J. Jordan, a book-printer, dated 22nd May, 1839, appeared in the *London Mechanics' Magazine*, published on the 8th June following. In this letter, Mr. Jordan states that the perusal of the notice relative to a discovery of Professor Jacobi—which had been republished in the *Mechanics' Magazine*—recalled to his recollection some experiments performed by him about the commencement of the preceding summer—1838—with the view of obtaining impressions from engraved copper plates by the aid of galvanism. He then proceeded to describe his apparatus, which was a constant battery on Daniell's principle, and stated that, in making experiments with it, he remarked, on removing the deposited copper, that the surface in contact with the plate equalled the latter in smoothness and polish, from which it occurred to him, that if the surface of the plate was engraved, an impression might be obtained from it. This, he added, was found to be the case; for, on detaching the precipitated metal, the most delicate and superficial markings, from the fine particles of powder used in polishing, to the deeper touches of a needle or graver, exhibited their correspondent impressions in relief with great fidelity. Mr. Jordan proceeded in his letter to throw out some suggestions—which have been subsequently acted on with great success—for taking fac-similes by this process, of coins, medals, and other articles.

Process of Electrotype.—The art of electro-metallurgy may be considered as divided into two branches, the first and simpler of which consists in the arts of plating and gilding, or the mere deposition of metals on metallic or conducting substances; the second, or the art of electrotype, properly so called, consists in copying coins, medals, or other productions of art by electro-chemical agency. The second process, though the least important in a manufacturing or industrial view, is the more complex, as requiring the formation of moulds; but as it is the branch which is usually cultivated by the amateur, and which will allow of a complete exposition of the process with a battery of a single cell, it may be desirable to begin the elucidation of the practical details of the subject with this department.

The galvanic combination employed for this purpose is generally either a DANIELL'S or a SMEE'S battery. The former may be taken to illustrate, within small compass, the general details of the process. Let it be assumed, therefore, that Fig. 434 is a battery on this principle, differing, however, from DANIELL'S original construction in this, that the outer vessel, E, is of glass or earthenware, and that B, the medal or mould to be copied, performs the part of the negative plate, instead of the copper vessel described in the original form of the battery—page 788. E is charged with a nearly saturated solution of sulphate of copper; D is the porous vessel of baked porcelain, or any other porous material, filled with dilute sulphuric acid to the level of the copper solution in the jar, E. A copper wire, C, to one end of which is attached the medal or mould, B, is fixed at the other to the rod of amalgamated zinc, A. The zinc rod is inserted in the porous vessel, so as to rest upon its rim by a wooden pin passed through it, as shown in the figure, and the copper wire, C, is bent, so that the coin or medal is suspended in the sulphate of copper in the outer vessel. To keep the fluid saturated, or nearly so, some crystals of the cupreous salt are placed on the colander or perforated shelf, near the top of the jar.

Fig. 434.



When this arrangement has been made, the action immediately commences, and assuming B to be a medal or coin, or a mould of some conducting material, a coating of metallic copper is soon deposited upon it.

Such is a general plan of the very simple arrangement adopted in this beautiful process, and if it were merely the object to cover the medal or mould, B, with a coating of metallic copper, this arrangement would be quite sufficient. It is obvious, however, that on removing the metallic deposit, the impression will be found reversed, and that, to procure an exact copy or fac-simile of a coin or medal, or any other work of art, a mould must be taken on which to precipitate the metal. In the copying process, therefore, the material and formation of the moulds, and other points of importance, require attention in the first place.

PREPARATION OF MOULDS.—In the early stages of the art of electrotype, the deposition of the metals could only be effected on metallic substances, and therefore there were only two processes which could be successfully employed in the preparation of moulds—either the formation of a mould by deposition on the model, employing the electrotype process itself for this purpose, or by taking the impression of the model on a soft metal, or a metal in a state of semi-fusion, and using this for a mould. In the rapid progress of the art, however, different ingenious plans have been suggested, by which the surfaces of non-metallic substances can be so prepared as to receive a metallic deposit by the electrotype process.

By Deposition.—Assuming that the object of which a fac-simile is required, is a coin or medal, which is one of the simplest cases, the metal is deposited upon it in the manner already described, and this metallic deposit, when removed, will obviously serve the purpose of a mould, on which, by a mere repetition of the same process, a perfect fac-simile of the model may be deposited. In both processes, however, certain precautions must be taken to insure, in the first place, a good deposition of the copper only upon one surface of the medal or mould, and, secondly, to secure the means of removing the deposited coating. The method of accomplishing these objects is very simple. In the first place, a fine copper wire is wound, at one end, round the edge of the medal, and fastened by twisting, so as to secure it firmly as in a ring; the back of the medal is then covered with a coating of wax or gutta percha, which must be carried over the edges, and a little way up the wire, but so as to leave the face of the medal quite clear; this insures the deposition of the copper only on that part of the medal which is to be copied. If the deposit were allowed to form on the back, it would be impossible to remove it without using the file. But even when confined to the face of the medal, another precaution must be taken to render it easy of removal. For this purpose, the exposed part of the medal, after being well cleaned, must be moistened with sweet oil, and then rubbed with a bit of silk till it has the appearance of being dry; or, without using the oil at all, it may be brushed over with black-lead until it acquires a bronze appearance. The other end of the wire is then attached to the zinc, and the medal is suspended in the copper solution with its face to the zinc, at the distance of an inch or less from the porous vessel. Deposition will immediately commence, and if the whole is in good working order, a coating of sufficient thickness will be formed in twenty-four hours. This may then be separated from the medal without difficulty; and by adopting the same precautions, it may be employed as a mould for successively receiving, by deposition, any number of fac-similes of the original.

Moulds in fusible metal.—It has been stated that Mr. SPENCER, in his early experiments, employed lead in its solid and natural state to receive the impressions of types and other objects which he intended to copy by the electrotype process. It is evident, however, that moulds taken in this manner must have been very imperfect, besides being limited in their application on account of the pressure required. The only metallic moulds now formed by impression are in fusible metal—a term applied to alloys of two or more metals, which, in combination, melt at very low temperatures. Mr. NAPIER, in his excellent work on Electro-metallurgy, gives the following as examples of compositions which are found to be suitable for this purpose:—

Tin.		Lead.		Bismuth.		[illegible]
1	......	1	......	2	......	0
1	......	2	......	3	......	0
1	......	0	......	1	......	1

Any of these compositions melt at a temperature below boiling water. To prepare them, the ingredients are fused together in an iron ladle, poured out, broken up, and remelted two or three times, so as to secure their intimate mixture with each other. The medal or coin to be copied is brushed over with a little sweet oil, using a very soft brush, and taking care to brush the oil well into all parts of the surface, which is then wiped with a piece of cotton wool. The edge of the medal is then bound round with a slip of tin or card, so that the edge of the slip may rise about a quarter of an inch above the most prominent part of the face of the medal. The alloy, in a state of fusion, is now poured into a saucer or small wooden tray, and when it begins to *set*, or has cooled down into a semi-solid mass, the operator brings the medal suddenly upon it, face downwards. When cold, the slip around the medal is removed, and the mould is easily separated. This mould is used in the same way, and with the same precautions, as the preceding.

Non-metallic Moulds.—As the metals are deposited from their salts, by galvanic action, only on conducting substances, the electrotype, as already stated, was limited in its first stages to deposition on metals. This was a barrier to its useful application for many important purposes. Moulds from non-metallic objects could not be taken by deposition, and moulds formed by impression could not be taken in the substances best adapted for such uses. This difficulty was first overcome by Mr. **ROBERT MURRAY**, who found that metallic deposition was effected even on non-conducting substances, by previously rubbing them over with the substance known as plumbago, graphite, or black-lead. This discovery, simple as it seems, immediately rendered the electrotype almost universal in its applications. It opened up a wide field for its cultivation, struck down the only bar to its progress, and no greater boon could have been conferred on the cultivators of this delightful art. Casts in plaster of Paris, figures or mouldings in wax, engravings in wood or any other material — even the innumerable graceful forms of natural objects, could now be represented and reproduced with facility in all the durability and brilliance of even the most precious metals.

In speaking of this application of plumbago, **SMEE** remarks that as a discovery it is fully equal in value to that of the electrotype itself. Its highest recommendation is its simplicity. The first use of it was made by Mr. **MURRAY**, in January, 1840; but notwithstanding its importance, that gentleman took no measures to secure even the credit of the discovery. With characteristic modesty, he only announced it orally at one of the conversazionés of the Royal Institution, and not by any written communication.

With the use of this valuable adjunct to the electrotype process, moulds may be formed of any suitable ductile, plastic, or easily fused material.

Bees'-wax, gutta percha, plaster of Paris, or compositions of bees'-wax with stearine, rosin, or other substances, in certain proportions, may now be successfully employed for that purpose. Bees'-wax, with or without stearine, is prepared for moulds by melting it over a slow fire, then stirring into it a little white-lead —about one ounce to the pound of wax—and afterwards remelting the mixture two or three times. The medal is prepared in the same manner as for moulds of fusible metal, and having been encircled with the slip of card, the melted wax is poured upon it, not too hot. Moulds of plaster of Paris are prepared with the finest material, mixed with sufficient water to give it, when well stirred, the consistence of thick cream. A small portion of this is first poured upon the face of the medal, prepared as in the preceding cases, and carefully brushed into every part of the surface to prevent the formation of air-bubbles, after which the rest is poured on till it rises to the edge of the circular rim. In an hour it will sufficiently consolidate to be removed with safety. It is then to be thoroughly dried at the fire, and afterwards saturated with wax at the impressed surface, when, on receiving a coating of plumbago, the mould will be ready for use. But except when very large moulds are required, plaster being found inferior to wax, is rarely employed for the purpose.

One of the best materials for moulding is gutta percha. In using this substance, it is heated in boiling water till quite soft; the medal is surrounded with a metallic rim, or placed with its back down in a saucer of the same form; the gutta percha is pressed upon the medal till it stands above the edge of the rim; additional pressure is then applied by a common copying press, and continued till the gutta percha is quite cold. Mr. **NAPIER** states that, when sufficient force is applied, the impressions taken in this way are generally very fine; and gutta percha possesses the advantage of readily taking on the plumbago.

Mr. **GORE** recommends, as an excellent composition for moulds, a mixture consisting of two parts of gutta percha and one part of Jeffrey's marine glue. The latter, in small pieces, is melted at a gentle heat in an iron ladle; the gutta percha, also in minute fragments, is then added, and the whole stirred until thoroughly incorporated. This substance, says Mr. **GORE**, presents several important advantages over gutta percha alone as a moulding material; it is softer when heated, and takes a much sharper impression; it contracts more in cooling, and may therefore be more easily removed from the original; in taking the black-lead it is most excellent, far superior to gutta percha; and with ordinary care many copies in copper may be taken from it by deposition.

Wax moulds are sometimes taken from medallions or other articles composed of plaster of Paris; or, by brushing the face of the model with plumbago, copper moulds may be deposited upon them by the usual electrotype process. In both cases the plaster of Paris must be saturated with boiled linseed oil, and then laid aside to dry, when the plaster will assume the appearance of polished marble. Moulds of plaster, or in fusible metal, may be taken in a similar manner from plaster models; but in these cases, to prevent adhesion, the latter must be saturated with a mixture of soap and tallow, prepared by boiling in water over a clear fire, and used by potters under the name of *lacquer*.

Elastic Moulds.—It is evident that all the preceding preparations can only be applied to the taking of moulds from such objects as coins, medals, medallions, or figures, of which one side only is to be copied at one operation. It is true, that by taking the different sides successively, and afterwards joining the different pieces together, a perfect fac-simile of many objects may thus be formed in deposited metal by the electrotype process, but still an effective method was wanting of taking a mould of any kind of model, such as a bust or statuette, or the infinite variety of natural objects, in one piece. This has been ingeniously effected by using moulds of an elastic material, as patented by Mr. **PARKES** of Birmingham. The composition which he uses for this purpose is similar to that employed by letterpress printers for their inking-rollers, and consists of a mixture of glue and treacle, in the proportion of four pounds of the former to one of the latter. The glue is steeped for several hours in as much water as will moisten it thoroughly; it is then put into a metallic vessel, which is placed in a bath of boiling water. When the glue becomes fluid, the treacle is added, and the whole is well mixed by stirring. The object from which a mould is to be taken is then introduced into a cylindrical vessel of sufficient depth to allow the object to be more than covered by the composition when it is poured into the vessel. The object must be weighted, or otherwise fixed down to prevent it from floating; and if it be a small plaster bust, for example, this may be effected by filling its interior with sand, and then covering the hole at bottom with a piece of paper, which must be pasted on to prevent the composition from entering. The vessel is then oiled in the inside; the bust also is drenched in oil, and placed upright in the vessel. The composition is now poured in, till the figure is covered to the depth of an inch. The whole must stand till perfectly cool throughout, after which it is taken out by inverting the vessel upon a table. The mould is then to be cut up the back and round to the front of the head with a sharp knife, when it is carefully held open until an assistant lifts out the bust. It is then allowed to re-close, and tied round with a piece of brown paper to keep it firm, but at the same time in such a manner that no distortion may be produced.

The interior is now a perfect mould of the bust or other object; but it is composed of a soluble material, and therefore cannot be inserted in any electrolytic solution to receive a metallic deposit. It furnishes the means, however, of preparing in materials suitable for that purpose any number of casts or fac-similes of the model. The composition generally used for this purpose is a mixture of wax and rosin, with occasionally a little suet, stearine, or, by preference, deer's fat, if procurable. This mixture is melted, and having been allowed to stand till it just retains its fluidity, is carefully poured into the mould, and left to cool. If too hot when introduced, it would melt the mould. The object to be kept in view, therefore, in preparing the mixture, is to compose it of ingredients which will produce a composition, not only capable of taking a good cast, but retaining its fluidity at such a temperature that it may be poured into the mould without injuring it.

A perfect wax model of the bust or other figure is thus formed, and may be extracted from the mould in the same manner as the original model. Any number of successive casts may be taken by the same process, so long as the mould remains uninjured; and these, being covered with plumbago, or prepared by a patent process to be afterwards mentioned, may be employed to receive a copper deposit. When this deposit is sufficiently thick, the wax may be melted out, or the figure, with its copper deposit, may be sawn into two pieces, the wax figure abstracted, and the two halves of the copper readjusted together. In either case the operator is furnished with a copper mould, the interior of which may be cleaned and prepared, by washing with alcohol and acids, for receiving a deposit of one of the precious metals. A perfect fac-simile of the model is thus obtained in silver or gold, and the copper is dissolved off by acids which do not attack these metals.

Moulds of figures in plaster of Paris may be taken in copper by deposition in the same manner. The figure is first saturated with wax, then covered with any conducting substance; and copper deposited upon it of sufficient thickness to bear handling. In this case the figure, with its copper deposit, must be sawn in two, and the plaster separated by boiling. When a copper mould is thus obtained, it may be prepared to receive an interior deposit of copper or any other metal, if of copper or of any metal that yields to the same acids, the mould is removed by being peeled off.

PREPARATION OF NON-METALLIC OBJECTS TO RECEIVE DEPOSIT.—The use of graphite or plumbago for this purpose, and its first application by Mr. **MURRAY**, have been already noticed; but other substances have also been employed to give to the surface of the model or mould the requisite conducting properties.

Plumbago is generally used for small articles, such as medallions, or any non-metallic objects to which it can be applied with facility. It is laid on that part of the surface on which the deposit is required, with a hare's foot or soft brush. The surface of the object should be occasionally breathed upon to facilitate its adhesion, and any excess of the graphite blown off. The brushing must be continued until all the face, round to the wire or slip of copper forming the connections, has acquired a complete metallic lustre. Care must be taken to bring it into contact with the connecting wire, otherwise no deposit will be obtained. At the same time, in the case of a medallion, for example, it must not be carried round upon any part of the back, which would cause the object to be partially encased in the deposit, and the latter would be difficult of removal.

Mr. **GORE** remarks that there is the greatest difference between different specimens of black-lead in their value for this purpose—some causing the deposit to spread all over very quickly, whilst others scarcely cause it to spread at all. He recommends as the best he has found, and as possessing excellent qualities, **DIX**'s black-lead, which is sold in twopenny packets, and one of which will last a long time for amateur use.

When the object is large, complex, or much undercut, Mr. **PARKES**' patent process is generally used for imparting a conducting power to its surface. This is effected by covering the object with a film of gold or silver in the following manner:—Sixty-four grains of wax or tallow are melted, then eight grains of finely cut caoutchouc are dissolved in one hundred and sixty grains of bisulphide of carbon, to which the melted wax or tallow is added, and the mixture well shaken; sixty-four grains of phosphorus are now dissolved in nine hundred and sixty grains of the same solvent, and the resulting solution thoroughly mixed with the previous one. The silvering liquid is made by dissolving eighteen and a quarter grains of pure metal, in about twenty grains of nitric acid, and diluting with twenty ounces of distilled water. The gilding liquid is made by dissolving five and a half grains of pure gold in about twenty-two grains of aqua-regia, and diluting with twenty ounces of distilled water.

The model or mould, after the connecting wire and a number of fine guiding wires directed into all the hollow and distant parts of its surface, have been joined to it, and its exterior perfectly dry, is dipped into the phosphorus solution for one minute, and after being drained is allowed to dry for half an hour or forty minutes. When dry it is immersed in the argentiferous solution for one or two minutes, until it appears like black china, when it is washed by pouring distilled water gently over it. The mould is then treated in a similar way with the gold solution, which gives it a yellowish bronze appearance, and after being washed it is ready to be coated.

This process is chiefly applied when a permanent coating of gold, silver, or any other metal is to be deposited upon the model. It may, however, be employed with advantage, in connection with the elastic mould, to deposit a mould of copper on the wax models formed by that process. The solutions of silver and gold, prepared as above, will last for a long time, and will serve for many operations. Either may be used separately with good effect, but the best results are obtained by dipping the object from which a mould is to be taken, in both solutions.

Surfaces of glass, says Mr. GORE, may also be prepared for receiving deposits by means of the phosphorus, silver and gold liquids, but not with very satisfactory results. He has adopted a much better method of preparing such surfaces by making use of DRAYTON and THOMPSON's patent process for silvering glass, which, when well executed, effects the object admirably; the deposit, whether of silver or copper, spreads instantaneously upon it, and the contact of the deposit with the glass is exceedingly close and perfect. It is done as follows: Take one part by weight of liquid ammonia, two parts of nitrate of silver, three parts of distilled water, and three parts of alcohol; dissolve the nitrate of silver in the water, add the ammonia, and shake them well, then add the alcohol and shake again, and allow it to settle until it is quite clear; pour off the clear liquid into the glass vessel to be silvered, which must be perfectly clean; then add to the clear liquid one quarter of a part of grape-sugar dissolved in weak spirit of wine and mix, and finally heat the liquid to about 150° or 160° Fahr., and in about twenty or thirty minutes the glass vessel will become silvered. The liquid may then be thrown away, the vessel gently rinsed with distilled water, the connection carefully made with the silver coating and the battery, and the deposit formed upon it in the ordinary way.

If a strongly adherent deposit is required upon glass or porcelain, the only plan to be pursued is to send the articles to a glass and porcelain gilder, and have gold-leaf burnt into their surfaces; a deposit, either of silver or copper, may then be easily made upon them by the battery process, and will be perfectly adherent.

DIFFERENT BATTERY ARRANGEMENTS.—Having explained in the preceding pages the general principles of the electrotype process, the methods of making various kinds of moulds, and of preparing non-metallic objects to receive a metallic deposit, the Editor will now proceed to describe the different arrangements of battery employed, and the practical details of the operations.

Single Cell Process.—This is the simplest arrangement, and has been already explained in general terms —page 794—with a view to illustrate the principles on which the electrotype acts. By reference to the figure which accompanies that explanation, it will be observed that in this arrangement the battery itself is employed to receive the object to be coated, or from which a mould is to be taken, and that the entire apparatus consists of a single cell of a Daniell battery, the principles of which were explained at page 788. It is manifest, indeed, that no other form of battery can be applied in this arrangement, because it is the only battery in which a metallic solution is employed. The mere operation of this battery is, therefore, in itself a good illustration of the electrotype process; the solution yields the metallic deposit, and the medal or other object intended to receive the deposit acts as the negative plate of the battery.

The single cell process is, however, only employed in operations on a small scale, and is, therefore, chiefly confined to amateurs. It furnishes a small, compact, and very convenient apparatus for such operations. A common glass tumbler or preserve jar may be employed for the outer vessel to hold the sulphate solution; for the porous tube, to contain the dilute acid, biscuit porcelain is the best material, and is formed in the shape of a narrow cylindrical vessel, which may be inserted in the tumbler or jar, leaving about an inch between them all round. A common lamp-glass, closed at the bottom with plaster of Paris, or with a piece of skin or bladder tied firmly round it, will serve the purpose sufficiently when nothing better is at hand. DANIELL employed the gullet of an ox for his porous vessel in his first experiments. Common unglazed garden pots, with the aperture at bottom closed by a cork, are found to be well adapted for the purpose, and may be employed with great advantage when the outer vessel is sufficiently large to contain them. The form of the vessel is unimportant. It may be a trough divided by a porous partition consisting of thin sycamore wood, plaster of Paris, or any other suitable material; but biscuit porcelain is the best.

Fig. 435.

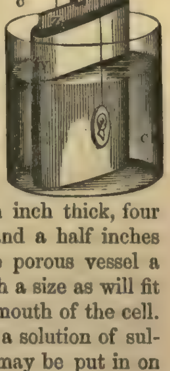


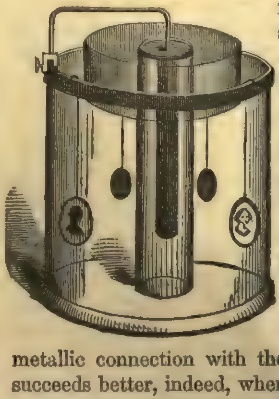
Fig. 435 represents an excellent form of apparatus for the single cell process. It consists of a large preserve jar or glass tumbler, C C, and a flat porous vessel, V, about half an inch thick, four inches in depth, and three to three and a half inches broad, inside measure. Place in the porous vessel a piece of amalgamated zinc, Z, of such a size as will fit easily, and stand an inch above the mouth of the cell. When the outer vessel is filled with a solution of sulphate of copper, a series of medals may be put in on both sides of the porous cell, and the wires attached to the zinc plate.

The only fluids hitherto mentioned as employed in the single cell process have been sulphate of copper and dilute sulphuric acid—the former in the outer vessel containing the object to be coated, and the latter, which is termed the exciting solution, in the porous tube. But instead of the sulphuric acid, a solution of chloride of sodium, or sulphate of zinc, or chloride of ammonium, may be used with excellent results as the exciting fluid. In the batteries for working the French telegraphs, nothing but pure water is put into the porous cell. The water, indeed, is the real agent in oxidizing the zinc, and thereby exciting the action, but its conducting powers are improved, and the film of oxide which forms on the zinc is more rapidly dissolved off, by mixing with the water a little sulphuric or hydrochloric acid, or one or other of the salts above-mentioned. When sulphuric acid is used, the proportions which have been found by experience to be the best are twenty-four parts of water to one of acid.

For the other solution, the sulphate of copper—*blue vitriol* of commerce—is the salt uniformly employed when copper is the metal to be deposited. For preparing the solutions of other metals, instructions will be given in a future page, in treating of the separate battery process. To prepare the cupreous solution, dissolve in a quantity of cold water as much of the copper salt as it will take up; allow it to stand till quite clear, and then add about one-fourth more water. A new solution is improved by the addition of a few drops of sulphuric acid, or a little sulphate of zinc. When the battery is in operation, let some crystals of the sulphate be placed on a perforated shelf, or suspended in a bag near the surface of the fluid, not to bring it to a state of saturation, which is not desirable, but to maintain the original strength of the solution.

By carefully attending to these precautions, the simple apparatus of the single cell may be applied with the best results for operations on a small scale; and by connecting with the zinc rod or plate a sufficient number of copper wires, any corresponding number of medals or other objects may be suspended in the cupreous liquid. This is very conveniently effected by the apparatus represented in Fig. 436, which shows the zinc connected by a wire and binding screw with a metal rim; and from the latter can be hung several moulds, all of which will thus be in metallic connection with the zinc rod. The process succeeds better, indeed, when several moulds are thus operated upon at once than when only one is introduced.

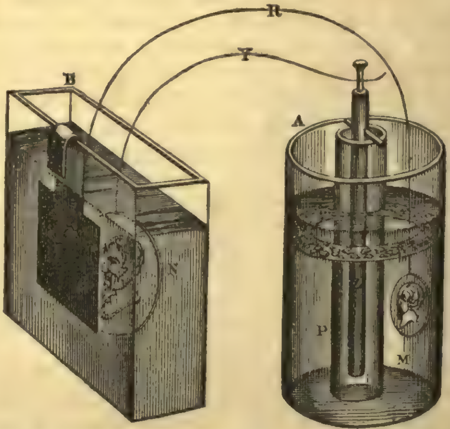
Fig. 436.



Separate Battery Process.—As the application of plumbago to impart a conducting power to the surface of non-metallic bodies was the first important step in the progress of electro-metallurgy, so it may be said that the second was the use of a separate or detached battery to work the chemical machinery of the process. Mr. Mason and Professor Jacobi had the honor of suggesting the second improvement, which is now almost universally applied in electro-metallurgical operations on the large scale. The battery being in a separate vessel from that in which the articles are placed to receive their metallic deposit, may thus be adjusted to any required power; the vessels or vats, in which the deposition is performed, may be made of any capacity; their fluid contents may be changed or renewed, and the articles immersed in the solution or withdrawn, after receiving the deposit, without interfering with the steady working of the battery; the latter may also be replenished or replaced, either in whole or in part, without interfering with the articles immersed; and lastly, a battery of any intensity or any convenient form may be used, whereas, in the single cell process, the choice is limited to Daniell's, and the power, as its name expresses, to a single pair.

The separate battery, as first suggested by Mason, was, however, a combination of the single cell process above described, with the use of a separate vessel, to which the electric current was conducted from the medal or other object suspended in the battery. This arrangement is shown in Fig. 437, where it will be seen that one part of the apparatus consists of a single cell, A, of a Daniell's battery with its porous tube, P; but that the medal, N, connected with the zinc rod by the wire, Y, is suspended in a separate vessel, B. This vessel, like the jar of the battery, contains a solution of sulphate of copper, and a plate of copper, C, is suspended within it, opposite and parallel to the medal, N. Another wire, R, connects the plate C with the medal, M, in the jar, A. By this arrangement, the electric current proceeds from the zinc, Z, through the porous vessel and the fluid media, to the medal, M, from which it passes by the wire, R, to the plate of copper, C; from this, through the sulphate solution in the vessel, B, to the medal, N, and back by the wire, Y, to the zinc rod, so that, as regards the medal, M, the action is precisely the same in principle, though not in degree, as if the wire, R, by which that medal is suspended, were a

Fig. 437.



mere continuation of the wire, Y, or were itself directly connected with the zinc rod. The action is not the same in degree, for the current, in passing from R to Y, through the cupreous solution in the vessel, B, encounters greater resistance than if it were transmitted directly by a wire from the medal, M, to the zinc rod. To compensate, however, for the slower action, additional duty is performed; for the current, in passing from C to N, decomposes the solution in the vessel, B; and while M is receiving a deposit in A, the medal or any other object, N, in the other vessel, B, is receiving an equivalent deposit at the same time.

It is worthy of remark that, by this arrangement, no crystals of the sulphate require to be suspended in B; for while, by the galvanic action, the copper from the solution in that vessel is transferred to the mould, the copper sheet is at the same time dissolved by the liberated sulphuric acid, with which it is converted into sulphate of copper, thus keeping up the strength of the solution without the addition of crystals of that salt.

In this case, also, the electricity, having to pass through a second solution, is made to perform double duty. For each ounce of zinc dissolved, two ounces of copper are deposited, and therefore, when time is of no importance, this arrangement is more economical than by the single cell. The additional resistance encountered by the current, however, in passing from C to N, requires about double the time for the operation. Mr. Napier found that, while the mould in a single cell apparatus had gained 100 grains, and the zinc plate lost 108 grains, the moulds in the two cells of Mr. Mason's arrangement had, in the same circumstances, and during the same time, received an aggregate deposit of 60 grains for 35 zinc dissolved. But,

$$60 : 35 :: 100 : 58{\cdot}3.$$

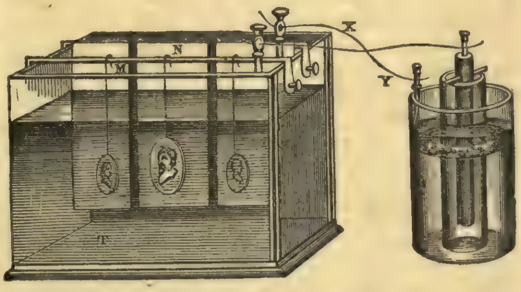
By the latter arrangement, therefore, not quite 60 grains of zinc—instead of 108 by the single cell—would have been required for the deposit of 100 grains of copper; but the loss of time would have been nearly double—a circumstance often of little importance, indeed, in conducting an operation that does not require constant attention.

From Mason's combination of the single cell apparatus with a separate decomposition vessel, one step only required to be taken to bring the apparatus to the form in which it is now most commonly used in electro-metallurgical operations on the large scale. This improvement was soon made, and consisted in using the battery simply to generate the current, and confining entirely to a separate vessel the objects intended to receive the metallic deposit. This arrangement has some important advantages. The galvanic battery and precipitating trough, says Smee, is the process almost universally adopted for all large objects, and there are many reasons why it should be employed. In the first place, one is enabled to regulate the quantity of electricity to the strength of the solution far better than by any other method; secondly, to keep up nearly a uniform strength of solution; and lastly, the process is frequently cheaper. To these the further advantage may be added, that any suitable description of battery may be used, instead of the operator being limited to Daniell's, as with the single cell, and that it is sometimes found convenient, in electro-metallurgical establishments, to have the batteries in one room and the troughs in another, the connections between them being formed by thick wires or ribands of copper carried through the intervening partitions.

This arrangement is exactly the same in principle as that illustrated by Fig. 412, p. 783, where the wire which connects the two plates is supposed to be broken, and its ends, at the point of fracture, introduced into the fluid contained in the vessel, B. In that case, the current which formerly proceeded from the copper, C, to the zinc, Z, through the unbroken wire, is simply continued through the fluid in A, which now forms a part of its course, but offers much greater resistance than if the metallic communication were uninterrupted. The degree of resistance will vary with the nature of the fluid, and the mass or thickness of it interposed between the ends of the wires. These extremities are termed the *electrodes*, or passages by which the electricity enters the fluid at one side, and emerges from it at the other. Pure water is a bad conductor, and offers, therefore, very great resistance; but sulphate of copper and other solutions employed in electro-metallurgical processes are good liquid conductors.

This method of procedure will be better understood from the annexed engraving—Fig. 438—where B is a cell of Daniell's battery, and T the decomposition trough.

Fig. 438.

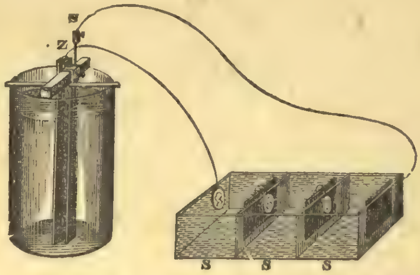


In this case, the battery is one of Daniell's original cells, having the outer vessel of copper, as described at page 788; or a cylinder or sheet of copper immersed in the outer liquid will serve the same purpose; M and N are brass rods fixed longitudinally over the trough; to the former are suspended the moulds, and to the latter sheets of copper exactly facing the moulds; the zinc of the battery is connected with the rod, N, by the wire, Y, and the copper of the battery with the rod, M, by the wire, X.

The motive power is here represented as one cell of Daniell's battery; but it is manifest that Wollaston's, or Smee's, or Grove's, all of which have been already described, may be employed in this arrangement; and one or more cells may be applied according to the power of the battery, the nature of the operation, and the amount of resistance to be overcome.

The trough may also be divided into separate cells. Thus, in the next engraving—Fig. 439—a Smee's battery is shown in connection with a trough divided by water-tight partitions into three cells, S S S. In these cells the galvanic series is made by alternating the metal to be dissolved, with the object to receive the deposit, the last mould being joined to the zinc, z, of the battery, and the last copper with the silver, s.

Fig 439.



When this form of precipitating trough is used, the positive plates employed should be large, and the liquid rendered as conducting as possible, to lessen resistance. But even when these precautions are taken, it does not appear to possess any important advantage over the common undivided trough represented in the preceding figure. It is true that the electricity from the battery, passing through all the cells in succession, reduces its equivalent in each. Thus, the reduction of one ounce of zinc in the battery would deposit the same amount of copper multiplied by the number of cells, whereas, in the ordinary single trough, whatever be the number of moulds immersed, the reduction of one ounce of zinc will only produce a deposit of one ounce of copper on the whole. But this apparent advantage is neutralized by the additional resistance to the current, in having to pass through the fluid of each cell in succession, whereas, with the undivided trough, the current has only to pass once through an equal thickness of solution. The resistance is therefore increased in proportion to the number of cells into which the precipitating trough is divided; and the number of pairs of plates of which the battery is composed would require to be augmented in the same proportion, to give intensity sufficient to overcome this resistance. The mere increasing of the size of the plates would not effect the object; for, as was previously remarked, the intensity of voltaic electricity, or its power of overcoming resistance, depends upon the number of the pairs of plates, and not on their magnitude.

Having stated that any form of battery may be used with a separate decomposing trough, either compound or single, it becomes a matter of interest and importance to compare the relative decomposing power of different batteries. With electrodes double the size of the zinc plates, and all at equal distances, namely, one inch apart, Mr. **Napier** found the following results, employing only one pair of plates for each battery:—

		In one hour.
Grove's battery	deposited	104 grains.
Single cell	"	62 "
Daniell's	"	33 "
Smee's	"	22 "
Wollaston's	"	18 "

But the same chemist observes that the first hour of the action of most batteries differs from any hour afterwards, so that one kind of battery may be most useful for a short time, and another sort if the action is to be continued for a length of time. He gives the following table as illustrating this remark, the conditions being the same as in the last experiment, or showing, in fact, the hourly results of the last experiment continued for seven successive hours:—

	1 hour.	2 hours.	3 hours.	4 hours	5 hours.	6 hours	7 hours.	Total.
								grains.
Grove's battery,	104	86	66	60	54	49	45	464
Single cell, ...	62	57	54	46	39	29	24	311
Daniell's,......	33	35	34	32	32	30	31	227
Smee's,.........	22	16	14	11	12	11	10	96
Wollaston's,....	18	14	15	12	11	10	10	90

From these results it will appear that **Grove's** is by far the most efficient battery; but the nitrous fumes which it evolves being highly inconvenient and deleterious, it is somewhat difficult to manage, as well as expensive in the first construction. **Grove's** battery is therefore little used for electro-metallurgical purposes. When a separate battery is employed, which is now uniformly the case in electro-plating establishments, **Smee's** and **Wollaston's** batteries, though slower in their operation than the others, are found to be the most convenient and economical in practice.

There are various peculiar applications of coating with copper; but before giving any account of these it will be desirable to state the processes for the deposition of other metals, especially gold and silver.

Electro-Silvering.—The old mode of silver-plating, which is still practised at Sheffield to some extent, consists in taking a piece of silver of nearly the standard of purity used for coining, soldering this upon a bar of copper, and subjecting the metals thus united to the dilating process of heavy rollers. By this process, as the two metals extend equally, the silver is reduced to an exceedingly thin covering. The plated metal is then manufactured into the required shape, and different parts are soldered together. The handles, edges, and ornaments of vessels, or other objects, are made of thin silver rolled to about a square foot to the ounce, and then struck in a die, and the hollow parts filled up with an alloy of lead and tin. The dies used in these operations at some manufactories are stated to have cost many thousand pounds. This alone is a serious objection to the old method; but its principal drawback consists in the fact, that the articles can only be plated by this process *before* being manufactured into the required form, and an article so plated, when worn through in any part, was valueless before the introduction of the electro-process. There are other objections to the old method, but the heavy restrictions on taste and design which it imposes, compared with the entire freedom and facility of merely depositing the silver by electrical agency on articles already manufactured, and of any suitable metal, constitute a disadvantage so obvious that it cannot be expected to compete successfully with the new process.

It was some time before the electrotype was applied to the deposition of any metal but copper. The first practical method of depositing the noble metals with a satisfactory result was patented by the Messrs. **Elkington**. The solutions they employ are the argento-cyanide and auro-cyanide of potassium—the former to deposit silver, and the latter for gold.

The argento-cyanide, or silvering solution, consists of cyanide of silver dissolved in cyanide of potassium. This solution may be prepared in various ways, but it will be sufficient to indicate the two most eligible processes. One of these is performed by simple chemical mixture, and the other with the aid of a battery.

To prepare the solution by the chemical method, metallic silver is dissolved in four parts of nitric acid, diluted with one part of water; the diluted acid is heated in a vessel, and the silver added by degrees until all dissolved. A solution of nitrate of silver—lunar caustic—is thus formed, which is transferred to a large vessel, and further diluted with ten parts water. Dissolved cyanide of potassium is then added so long as a white precipitate falls. This precipitate is cyanide of silver. When it has sufficiently settled down, the clear liquor is carefully decanted, and after the precipitate has been well washed to remove the soluble salts, a solution of cyanide of potassium is added to it until it is completely dissolved. The resulting liquid constitutes the cyanide of potassium and silver, and forms the silvering menstruum, which should be diluted to such an extent as to contain one ounce of silver in the gallon. The salts of potassa *in strong solution* exercise a slightly solvent action on cyanide of silver, and it is to prevent a loss from this source that the nitrate of silver is diluted previous to adding the cyanide in the first instance.

But the best and most economical method of preparing the silver solution, and that which is generally employed in electro-metallurgical factories, is by the use of the battery. To make a depositing liquid containing one ounce of silver to the gallon by this process, make a solution of cyanide of potassium of the strength of one and a quarter ounce to the gallon of water employed; then place a porous vessel in this mixture, so as to stand with its mouth at least one inch above the surface; fill this vessel with the same liquid to the level of the liquid in the outside vessel; put into the porous cell a sheet of copper or iron, and connect it with the zinc terminal of a battery; in the bath or large solution put a sheet of silver, and connect this with the copper terminal. By the aid of a WOLLASTON's battery, consisting of four pair of plates, the zinc ones being about six inches square, the required quantity of silver will be dissolved in the bath in the course of a few hours, forming the cyanide of potassium and silver, which is now ready for use. By weighing the sheet of silver before and after the operation, the quantity that has been dissolved will be ascertained.

From this solution, prepared by either of these processes, silver may be deposited upon any metal; but copper, brass, and German silver, are the best for plating upon. Lead is by no means difficult to plate, but the two metals have generally a weak adhesion, because the lead, although made perfectly clean, becomes in part coated with an insoluble cyanide as soon as immersed in the solution. From its softness, also, it readily yields to the pressure of the burnisher. Tin, zinc, iron, pewter, and Britannia metal are not so easily coated with silver as lead; but all are occasionally plated by the electro-process, though the metal now most generally used for all new work is German silver.

Whatever be the nature of the metals to be plated, the articles intended for this purpose must not be immersed in the silver solution until they have been carefully prepared to receive the deposit. In plating and gilding, a principal object is to render the deposited metal as fixed and permanent as possible; but if the surface of the article has not been properly prepared, the deposit will rise up in blisters, which a touch of the burnisher will rub off, and the whole operation will be useless. The careful preparation of the articles is therefore a point of vital importance

This may be performed by the wet or the dry method. M. BECQUEREL prefers the latter, which, however, can only be applied when the work of the article is not of a delicate character. The object of the operation in both cases is to remove from the surface intended to receive the deposit every particle of grease and oxide, which, if present in the smallest quantity, tend to diminish the adhesion. The dry process simply consists in scouring the articles with sand, glass, or emery paper, or with very fine pumice-stone powder, using for this purpose clean brushes perfectly free from grease, or bundles of fine brass wire, technically called scratch-brushes. Particular care must be taken to avoid contact with the moisture of the hand, which both oxidizes and greases the surface. The alleged advantage of the dry over the humid process is, that in the latter case, an interval, however short, must always occur between the act of removing the article from its last liquid bath, and placing it in the solution of the metal to be deposited; and during even that momentary interval the article, or some part of it, is liable to acquire a film of oxide.

From the nature of the articles subjected to the process, the number of cases in which the dry method is available is, however, very limited. The other method is, therefore, generally practised in factories, and by the exercise of due care the adhesion may be rendered by this process quite perfect. It consists in alternately subjecting the articles to alkaline and acid solutions, the former to free them from grease, and the latter from oxide; brushing or rubbing with fine sand, and rinsing in pure water. The article is first boiled in a lie of caustic potassa or soda, containing about half a pound of the alkali to the gallon of water, and then dipped into nitric acid, diluted to such an extent as merely to act upon the metal. It is then scoured with a hard brush and sand, of which a very fine description obtained from the Isle of Wight is the best; after which it is washed thoroughly, and dried, and then weighed. A copper wire is now attached to it, either by twisting it round the article or putting it through any open part. It is then dipped into nitric acid, containing ten per cent. of sulphuric acid, or into a mixture technically termed *pickle*, and composed as follows:—

Sulphuric acid, ...	64 parts.
Water, ...	64 „
Nitric acid, ...	32 „
Hydrochloric acid, ...	1 „

It is quickly removed from this bath, washed by immersion in distilled water, and then without loss of a moment dipped in a solution of nitrate of mercury till the surface is white. From this the article is taken out and *struck* in the silver solution; that is to say, it is suspended by the wire connected with the zinc of the battery, when it is immediately coated with a thin film of silver. This operation is termed *striking*, and batteries of intensity are used for this purpose. After a few seconds, it is taken out and well brushed. On the large scale, brushes of brass wire attached to a lathe are employed, but for small operations a little fine sand rubbed with a hard hair brush will effect the object, which is to remove any particles of foreign matter that may still adhere to the surface, and to test the completeness of the coating. The article is then washed in water, and replaced in the plating solution, and in the course of a few hours a coating of the thickness of tissue paper will be deposited upon it, having the beautiful matted appearance of dead silver.

If it is desired to preserve the dead surface, the object must be taken out, and immersed in boiling distilled water for a few minutes. On being withdrawn, it will dry immediately by its own heat, and then it must be placed under a glass shade, or otherwise protected from the action of the air, which, by forming a sulphide upon it, would tarnish it in a few days.

Mr. GORE remarks that the practical minutiæ of preparing the surfaces of various metals for receiving adhesive and non-adhesive coatings of different metals and in different liquids, vary considerably in different manufactories, and much information yet remains to be acquired respecting the particular methods required for particular metals and liquids, and from a want of this knowledge the most skilful operators occasionally fail in producing complete and strong adhesion, especially in coating Britannia metal, zinc, lead, tin or steel, with silver; iron or zinc with copper, *et cetera*.

Bright Deposit.—If a bright surface is wanted, this may be obtained either by burnishing, or by the addition to the silver solution of a little sulphide of carbon, which has the singular effect of throwing down a bright deposit. This remarkable fact was discovered in the following circumstances:—Some operators at the works of Messrs. ELKINGTON and MASON were engaged in experiments upon elastic moulds, and whilst coating them with silver in the depositing vat, the deposits taking place upon the various articles in that vat were observed to present very peculiar and unusual appearances, some of them being exceedingly bright in different parts; these appearances were referred to the presence of the elastic moulds, and from the known existence of bisulphide of carbon in the moulds, experiments were tried of adding portions of that liquid to a quantity of plating solution, which finally ended in success, and a patent was taken out by Messrs. LYONS and MILLWARD, March, 23, 1847. The best method of applying the sulphide is to put one or two ounces into a large bottle, and then fill it with strong silver solution; this mixture is allowed to stand for several days, shaking it occasionally, when it will be ready for use, and a little may be added to the plating solution as required.

Collodion and sulphur, sesquichloride of sulphur, or the hyposulphite of either potassa or soda, are also used for the same purposes, but to a less extent. A solution of iodine and gutta percha in chloroform is said to be more permanent in its effect than bisulphide of carbon.

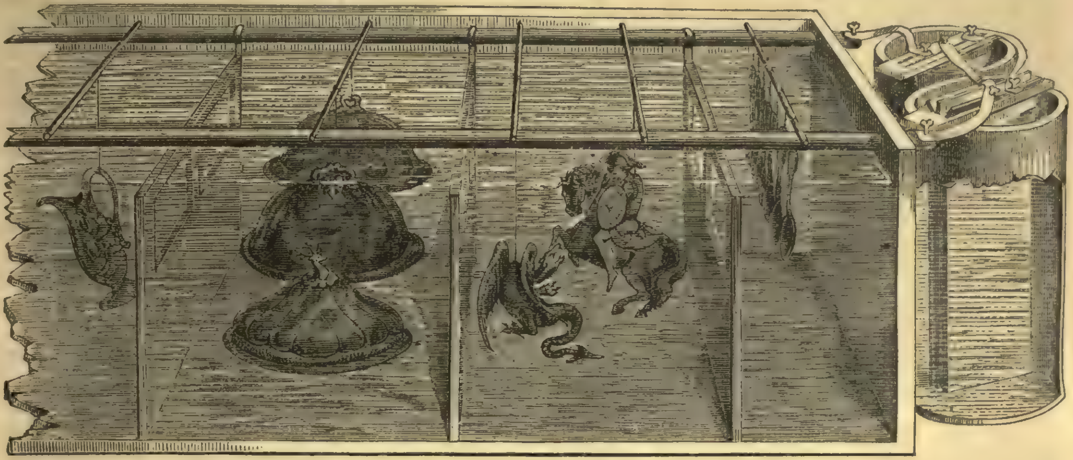
Mr. GORE remarks that a bright solution requires a large quantity and low intensity of battery-power to work it, and the anode in it is generally of a darker color than that in the ordinary liquid. It is much more difficult to operate with than the ordinary liquid; if it is not worked constantly and uniformly, it will lose its power of yielding bright metal; if any one of the articles which are being plated in it is disturbed or removed from the liquid and replaced, that one will not again receive a bright deposit, and the disturbance of the liquid by removing it will oftentimes cause all the neighboring ones to lose their brightness; or if too much brightening liquid is added, the solution will be considerably injured—indeed many silver solutions have been totally spoiled in this manner.

But the silver is generally deposited *dead*, which admits of burnishing either the whole surface, or any particular parts of it, by mechanical means. In that case, the article is first brushed over with a wire brush and old ale or beer, and then subjected to the usual process of burnishing by polishing the surface with bloodstone or bright steel.

Small articles, such as spoons, knives, forks, snuffers, *et cetera*, are generally wired before they are cleaned, that is, they have small copper wires, size number twenty or twenty-two of the Birmingham brass wire gauge, and about fifteen or eighteen inches long, twisted round them to suspend them by when in the vat, and to conduct the electricity; larger articles, such as teapots, jugs, *et cetera*, are generally wired at some advanced stage of the cleaning process after they have been scratched; and very large articles, such as fenders, hat-stands, large ornamental iron-work, *et cetera*, are not wired at all, but are suspended in the solution by strong copper or brass hooks; in cases where a very good and safe connection is required, the connecting wires are soldered to the articles.

It has been remarked, that when the article is *struck* in the silver solution, intensity batteries are used; but when afterwards immersed to receive the final deposit, batteries of volume are applied; or, in other words, batteries which furnish electricity in quantity, with greater or less intensity, according to the measure of resistance to be overcome. The power of the battery must vary according to the strength of the solution and amount of work to be done. In some of the large factories, the vats or plating vessels measure about six feet in length, by thirty inches in breadth and depth, and contain about two hundred gallons of solution, having generally one ounce of silver to the gallon. The annexed engraving—Fig. 440—is a correct representation of a silvering vat, with battery in action, as employed in the large works of Messrs. ELKINGTON of Birmingham; the manner of suspending the articles to be coated is also exhibited. The silver plates serving as electrodes are fixed upon light iron frames, which are not affected by the solution. These are attached at one corner to the rod which is connected by a copper riband with the copper terminal of the battery; the plates are entirely immersed in the solution, and partially divide the vat into compartments, as shown in the figure, so that a silver surface is exposed to each side of the articles. The latter are suspended by cross-bars, forming a metallic communication with the longitudinal rod which is connected with the zinc terminal. The batteries are those of SMEE or WOLLASTON, with plates about equal in length to the depth of the vat, and eight or nine inches in breadth.

Fig. 440.



For a vat of the capacity above-mentioned, six batteries of three pair intensity are sometimes employed, the zinc plates immersed in the acid measuring six inches by seven.

To ascertain the amount of metal deposited, it is only necessary to weigh the articles carefully before and after the operation.

When old articles are to be replated, the silver that remains upon them must be taken off before they are subjected to a repetition of the process. This may be done either by chemical or mechanical agency. To remove the silver by the chemical method, the article is placed in a stoneware or copper vessel, containing some strong sulphuric acid, to which a little nitrate of potassa is added. This solution dissolves the silver without materially affecting the copper. When the silver is completely removed, the article is well washed, then passed through the alkaline lie, and the other preparatory operations for plating. The silver is recovered from the sulphuric acid when the latter is saturated with the metal, by adding a dilute solution of chloride of sodium, which throws down the silver as a chloride; this precipitate is then collected, and the silver is obtained in a metallic state by fusing with carbonate of potassa.

The mechanical method is generally preferred, and is performed in the factories by means of a hard circular brush, fixed upon a lathe, and a thin paste made of oil and fine pumice-stone powder. By this process, if skilfully managed, the article is not only stripped of its silver, but thoroughly smoothed and polished—a necessary preparation, which old plated articles are generally found to require even when stripped by the acid process. It is therefore the preferable method to strip and polish the articles at one operation. The brushings are collected, and subjected to a red heat in an iron vessel, and that which remains after burning is fused with carbonate of soda and potassa to recover the silver.

In all cases of electro-deposition of metals, and especially in using the double cyanide solutions, the metallic deposit, which ought to be perfectly smooth, is often disfigured by vertical lines or ridges, produced by the constant upward current of the lighter parts of the solution which are set free. This is prevented by keeping the articles in motion, and different plans have been suggested for this purpose. The rods to which the articles and plates are suspended, are generally fixed into a frame, supported on four small wheels, which run upon a kind of rail formed on the edges of the vat. When steam power is at command, a gentle oscillating movement may easily be communicated to this frame; but when there is no engine, the same may be accomplished by clockwork or other devices. The superintendent of a plating establishment in Glasgow produces the motion by a bent lever, one arm of which is connected with the frame by a cord or wire, and the other carries a small pan, into which water is allowed to drop from the spigot of the pipe which supplies the vat. When a certain quantity of water accumulates, its weight overbalances the slight resistance produced by the action of the frame on the other arm of the lever; the pan, in descending, empties its contents; and the frame which, by the motion of the lever, had been drawn forward on its rail, returns to its place by the action of gravity, the rail being slightly inclined for that purpose; or if the rail is horizontal, the frame may be drawn back to its position by the action of a spiral spring, connected with the end of the vat. The retreat of the frame raises the pan, and the same operation is repeated without any care or trouble on the part of the person in charge. The simplicity of this ingenious contrivance is not the least of its recommendations. The dropping of the water is certain and constant in its action; whereas, the operation even of a steam-engine is liable to interruptions, and mechanism moved by clockwork is not only more complex, but is often brought to a stand by the simple neglect of the attendants to wind it up.

If a solution contains much free cyanide, and by any means the battery power becomes suddenly weak towards the latter part of the day, the silver deposited upon the articles will be redissolved off, because the liquid about the dissolving plates having by the day's work become saturated with metal, and that about the articles having become full of free cyanide, the two —that is, the dissolving plates and the articles—form a kind of voltaic battery, which circulates a current of electricity in an opposite direction to the original one, and thus redissolves the deposited silver. Care must be taken to guard against this accident; which, however, will not occur where motion is kept up.

Electro-gilding.—Gilding was formerly performed by amalgamation. A mixture of finely-divided gold and mercury was rubbed over the object, and the mercury afterwards driven off by heat. This process was very detrimental to the health of the workmen, as the fumes of quicksilver are extremely poisonous. It is now almost entirely superseded by the electro-process, which is, in most cases, remarkably easy, and is performed in much the same manner as electro-silvering. The metal to receive the gold may be either platinum, palladium, silver, copper, tin, or indeed almost any other metal, when the auro-cyanide of potassium is employed.

This salt is frequently made by dissolving oxide of gold in a solution of cyanide of potassium. The oxide is prepared by dissolving gold in three parts of hydrochloric acid, and one of nitric acid, which forms the chloride; this is digested with calcined magnesia, and the gold is precipitated as an oxide.

But, as with the silver solution, the best process for preparing the auro-cyanide is by the battery. This is performed by arranging a piece of pure gold as the positive pole in a solution of cyanide of potassium; a porous cell is filled with the same liquid, and then introduced into the bath; a sheet of iron or copper is now placed in the cell in such a position as to face the sheet of gold in the bulk of the solution, and both metals are connected with the battery, as described for making the silver liquid. In fact, there is no difference between the two processes, except that a sheet of gold instead of one of silver is placed in the cyanide bath, and that in preparing the gold solution, and for all the operations of gilding by this method, the liquid must be heated to at least 130° Fahr. Having made the connections, the battery is allowed to remain in action until the quantity required has been dissolved, which may be ascertained by weighing the gold electrode from time to time, and observing how much it has lost. From one half to an ounce of gold in the gallon is the common strength of the liquid used in large operations; but a weaker solution is sufficient for gilding small articles.

The articles to be gilt are cleaned in the way described for silver; but as the process of gilding is generally performed upon silver articles, the previous immersion in nitric acid is, in that case, dispensed with. When cleaned and dried they are weighed, and one immersion is given, which merely imparts a blush of gold; they are then taken out, brushed, and reimmersed. If the battery and solution are in good order, three or four minutes will suffice to gild any small article. The hotter the solution, the more rapid the operation, and the less battery power is required. If kept at 130° to 150° Fahr., three or four plates may be used; but if raised to 200°, one pair will be sufficient. A convenient mode of applying the heat is to put the jar containing the solution into a vessel of water, which is kept at the boiling point; and as the liquid evaporates by being hot, distilled water must be added after each operation, to prepare it for the following day, as it is not so good to add the water immediately before proceeding to operate. The articles, when gilt, are again weighed, and the quantity of gold deposited is thus ascertained.

Iron, tin, and lead are most frequently gilt by having a slight film of copper deposited on them immediately before being introduced into the auriferous bath. Silver articles, before they are gilt, are merely well brushed, and kept in clean water until they are immersed in the depositing fluid.

The accompanying woodcut—Fig. 441—illustrates the arrangement of the apparatus for electro-gilding as in operation at the establishment of Messrs. Elkington and Mason. The battery is represented by the letters, *a a;* the *gold-vat,* containing the double cyanide of gold and potassium, is denoted by *b*. The temperature of the solution is maintained by steam circulated in a pipe coiled round the vessel between its interior and exterior sides. *d, d, d,* are baths in which the operator from time to time rinses out the objects undergoing the gilding process. At *c*, one of these is seen, which, being filled with cyanide solution, and having the gold plate —connected with the positive pole of the battery—suspended inside, merely requires the application of the negative pole for the performance of the operation. The various ribands of metal connecting the bath with the battery are seen traversing the bench.

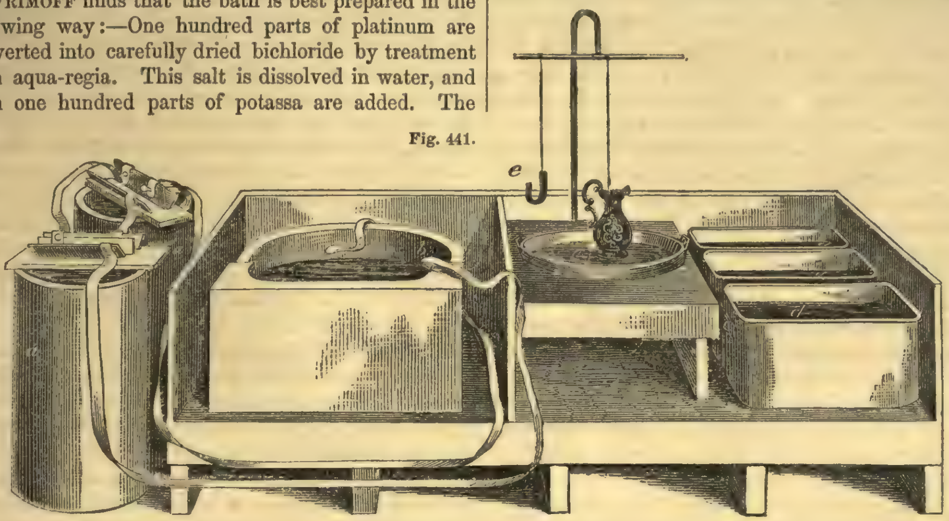
The color of the gold deposited very much depends on the strength of the battery and the temperature of the solution. By due attention to these points any desired shade may be obtained. If the battery is too strong, the hue will be black; if the battery is rather weak, and the solution too cold, the coating will be light-colored. When all the ingredients are properly regulated, the gold, on coming out of the solution, should be of a dark brownish-yellow; and this, when scratched, will yield a beautiful rich deep color.

To remove gold from articles before regilding, or when the gilding has been performed imperfectly, they may be put into strong nitric acid, to which, when the articles have been immersed, some chloride of sodium is added. This will dissolve off the gold from any metal without injuring the latter; but the mechanical method, by using the lathe-brush, as described for silver, is the best.

When the gold has been dissolved off, it may be recovered by diluting the acid, and then introducing soda or potassa till the acid is nearly neutral; after which a solution of sulphate of iron is added, so long as any precipitate falls by standing. This precipitate is then filtered; the filter with its contents is dried, and the precipitate is then fused with a little borax. Oxalic acid may be used instead of copperas with the same results. If the gold be brushed off, the washings are treated as described for silver, and fused with borax.

Electro-platinizing.—This process is similar to the preceding, but is attended with some difficulties. The depositing solution consists of the double chloride of platinum, and an alkali, which must be neutral. JEWRIMOFF finds that the bath is best prepared in the following way:—One hundred parts of platinum are converted into carefully dried bichloride by treatment with aqua-regia. This salt is dissolved in water, and then one hundred parts of potassa are added. The resulting precipitate is boiled with a solution containing seven hundred parts of oxalic acid. After this has been filtered, three hundred parts of caustic potassa are poured in. The liquid is now well adapted for electro-platinizing in the ordinary way. The object to be operated upon should be smooth, and thoroughly cleansed with an alkali before being introduced into the bath. The cathode must be of platinum, and inserted in the liquid in the manner already indicated for electro-gilding.

Fig. 441.



Platinum has also been deposited from solutions of its iodide, bromide, and the double chloride of platinum and sodium. The solution of double chloride of platinum and sodium is formed by adding one equivalent—58·5 parts—of common salt to one equivalent—169·7 parts—of bichloride of platinum, and dissolving the mixture in water. The resulting solution requires a very weak battery and a small anode of platinum to obtain a reguline deposit. A deposit of platinum in the state of a black powder, for platinizing silver plates, may be very easily obtained from it by adding a little sulphuric acid to the solution, and using a much stronger battery and a larger anode.

Electro-palladiating.—For this purpose a solution is prepared by dissolving ammonio-chloride of palladium in liquid ammonia, and the compound battery process employed with a small palladium pole; or palladio-cyanide of potassium may be used for the depositing solution. To form the palladio-cyanide, dissolve some cyanide of potassium in water, immerse a large palladium anode and a small bright cathode of iron or copper in it, and connect them with a small battery of one or two pairs, and continue the action until the cathode receives a good deposit; or, which is better, put the iron cathode in a porous cell, as described for gold and silver. The resulting solution is an excellent one. This metal adheres so firmly to copper, when deposited by this process, that its removal is impossible.

Electro-coppering.—It has been seen that in depositing copper on moulds by the single cell, or the battery process, a solution of sulphate of copper is used; but this solution is not fitted for depositing copper upon iron, steel, or zinc, with a view to adherence, because the electrical relations of these metals are unsuitable to that of the copper in the sulphate, and reduce the copper upon themselves by simple immersion, in which case it does not adhere. The depositing liquid generally employed for covering iron with copper, is a solution of cupro-cyanide of potassium. It is prepared by adding to a solution of sulphate of copper a solution of cyanide of potassa, so long as there is any precipitate formed, but not more, and washing the resulting precipitate until the percolations afford no milkiness with chloride of barium. Great care must be taken not to breathe the gas evolved, which is very poisonous.

Having washed the precipitate, it is dissolved by adding a solution of cyanide of potassium, and then filtered. Four ounces sulphide of copper will make a gallon of solution. This depositing liquid must be worked at a temperature of not less than from 150° to 200°. It forms an exception to the general rule, that if the electricity be so strong as to cause an evolution of gas at the electrode, the metal will be deposited in a granular form, for this depositing liquid will afford no reguline metal unless gas be freely evolved from the surface of the article on which the deposition is taking place. This fact renders necessary the employment of batteries of some intensity. The vessels for this solution are usually of copper, and are heated over a flue, or a sand bath. They then serve as the positive electrode of the battery.

After the iron has been cleansed, an immersion of five minutes is enough to produce upon it a film of copper, but if it is desired that the iron should have a thick coating, and as the cyanide of copper process is an expensive one, it is advisable to increase the coating by means of the single cell process with a nearly saturated solution of sulphate of copper. The cupreous bath should also be made as neutral as possible, by the addition of a little caustic soda.

Electro-zincing.—The depositing liquid employed for electro-zincing is made by dissolving two pounds of sulphate of zinc in a gallon of water.

To use this solution a separate battery and a zinc positive electrode are necessary. The metal is very readily deposited; but on plumbagoed surfaces, unless great precautions are observed, the metal assumes a crystalline texture, and, therefore, is very brittle. The best way to avoid this is to use a saturated solution of the salt, and to keep the article to be coated in constant motion.

Deposition of Cadmium.—For the electro-deposition of cadmium, the following is the process described in Messrs. **Russell** and **Woolrich's** patent, dated March 19, 1849:—Take cadmium and dissolve it in nitric acid, diluted with five or six times its bulk of water, at a temperature of about 80° or 100° Fahr., adding the diluted acid by degrees until the metal is all dissolved. To this solution of cadmium a solution of carbonate of soda—made by dissolving one pound of the ordinary crystals of soda in one gallon of water—is to be added until the cadmium is all precipitated; and the precipitate thus obtained is to be washed four or five times with tepid water; next add as much of a solution of cyanide of potassium as will dissolve the precipitate; after which, one-tenth more of the solution of cyanide of potassium is to be added to form *free* cyanide. The strength of this resulting liquid may vary, but the patentees prefer a solution containing six troy ounces of metal to the gallon. The solution is worked at about 100° Fahr., with a plate of cadmium as an anode.

Deposition of Nickel.—Mr. **Gore** deposited nickel in the state of reguline white metal from a solution of the double chloride of nickel and ammonia, by making a lump of metallic nickel the anode in a strong aqueous solution of hydrochlorate of ammonia—sal ammoniac—and passing a strong current of electricity through it for several hours, as described for gold and silver, until the liquid acquired a pale greenish-blue color; also by treating a solution of one part of arseniate of potash and five parts water in a similar manner. Nickel is likewise deposited from a solution formed by dissolving the pure metal in nitric acid, then precipitating it either by a solution of caustic potassa, carbonate of potassa, or cyanide of potassium; washing the precipitate, and dissolving it in a solution of potassium, and operating by means of a battery and an anode of pure nickel. Its appearance when deposited from this solution is said to be nearly equal in whiteness to silver, and its deposition has been proposed to be applied to the production of an inferior class of plated articles.

Deposition of Iron, Tin, and Lead.—Iron and tin are easily deposited, the former from its sulphate solution, the latter from its protochloride; and lead may be deposited either from its acid or alkaline solution, but with greater difficulty. No practical value has yet been attached to the deposition of these metals.

Deposition of Antimony.—Next to copper, antimony is one of the most easy metals to deposit in a coherent state, but does not spread over black-leaded gutta percha surfaces, nor does it adhere with any degree of firmness when deposited upon copper, brass, or iron; nor has the deposition of it been yet applied to any useful purpose, although bright deposits of considerable thickness may easily be obtained. The deposited metal, also, exhibits in certain circumstances very remarkable phenomena, which render it worthy of notice. It is readily deposited from a solution of the ordinary chloride of antimony—butter of antimony—as prepared for pharmaceutical purposes, by suspending a small piece of antimony as an anode, and using a very weak battery of one or at most two pairs. The mixed chlorides of antimony and ammonia form also an excellent depositing liquid. The appearance of antimony, when deposited from any of the chloride solutions by a weak and continuous current, is very brilliant, similar to highly-polished steel. The remarkable properties to which allusion has been made, appear when it is deposited rather rapidly, and seem to have been first observed by Mr. **Gore**, by whom they were described in the *Philosophical Magazine* for January, 1855, in the following terms:—If during any part of the time the deposit is progressing, the deposited antimony be taken out and struck gently or rubbed with any hard substance, such as metal or glass, an explosion occurs, with a small cloud of white vapor, sometimes with a flash of light, and nearly always with considerable heat, sufficient to burn one's fingers, melt gutta-percha, burn paper, and even scorch deal wood quite brown, especially if the deposit is thick; and invariably accompanied by fracture of the deposited metal; sometimes, if the process of deposition has been interrupted, and the deposited metal is not homogeneous, only a thin scale falls off—in such cases the heat and explosion are less; in other instances, where the process was regular and the metal homogeneous, the fracture extended quite through the metal to upwards of one-eighth of an inch in depth. He observed this phenomenon in about nine instances, in several of which the explosion took place even in the liquid, by striking the deposit against the glass containing vessel; and in one instance it occurred after the metal had been well washed with dilute hydrochloric acid, dried, and had remained out of the liquid several hours.

Since publishing these observations, Mr. **Gore** writes in the *Pharmaceutical Journal*, that he has met with the same phenomenon many times, and in several instances a deposit has been going on in the chloride solution, and has been removed an instant for examination, and the battery power—one cell of **Smee's**—has been increased by addition of acid, and upon the next examination, some hours afterwards, the deposit has been found cracked in many directions, as if a feeble explosion had occurred in the interval, the apparatus being meanwhile unmoved. It has been suggested that the deposit is a compound of antimony and hydrogen, and this idea is favoured by the observation, that when the metal is deposited very slowly indeed the explosions do not occur, and that in every case where an explosion took place the metal had been deposited more rapidly—the extra power probably depositing hydrogen also; which, instead of being as usual evolved, might, in its nascent state, combine with the metal and form an explosive compound. Mr. **Gore** hazards the additional suggestion, that the metal is deposited in a peculiar structural condition—a state of unequal mechanical tension, similar to that of unannealed glass, and that when broken, the closer aggregation of the particles develops heat and light.

Another peculiarity in the deposition of antimony from the chloride is, that if the cathode be sustained, partly in the liquid, and kept uniformly at that depth without disturbance, a deposit of the metal will occur upon it at the surface of the liquid, and spread out gradually in the form of a thin button all around—if it be a wire—and ultimately touch the anode if sufficiently near, lying as a circular sheet of metal upon the surface of the liquid, whilst the deposit beneath progresses very slowly. He has a button one inch and five-eighths in diameter, and one-sixteenth of an inch thick, formed in this way upon a piece of wire three-sixteenths of an inch thick, the part of deposit beneath the surface of the liquid being only half an inch in diameter. The battery used was a one-pair **Smee's**, and the process occupied about eighteen days.

Deposition of Bismuth.—Bismuth is easily deposited from a solution formed by dissolving either the nitrate or subnitrate of the metal in a mixture of nitric acid and water. It requires a much weaker current even than antimony to deposit in a bright coherent state. Its appearance, when slowly deposited, is a very beautiful white, with a faint pinkish tint, and having a fine silky lustre.

Deposition of Brass and other alloys.—The attempts that have been made to deposit alloys from their solutions, have not been attended with much success hitherto; but a process for depositing brass, patented by **Moriss** and **Johnson** in 1852, is said to be productive of good results. This process is as follows:—Dissolve one pound of cyanide of potassium, one pound of commercial carbonate of ammonia, two ounces of cyanide of copper, and one ounce of cyanide of zinc, in one gallon of water; and use the solution at 150° Fahr. with a large anode of brass and a powerful battery; or a solution may be taken of one pound of cyanide of potassium and one pound of carbonate of ammonia, dissolved in one gallon of water, and saturated with copper and zinc by means of a strong battery, with large brass anode and small cathode, until the latter receives a good deposit of brass, the solution being at about 150° Fahr. To increase the proportion of copper in the deposit, either add cyanide of potassium or raise the temperature of the liquid; and to increase the proportion of zinc in it, either add carbonate of ammonia or lower the temperature. Always use a large brass anode.

Mr. **Gore** states that of the different solutions for depositing brass which he has tried, the above is much the best, as by it reguline and thick deposits of brass of uniform color, and of any desired composition, may be obtained.

Steele's mode is to dissolve separately two and one quarter pounds of American potassa, and two and a half ounces of powdered acetate of copper, previously mixed with half a pint of strong ammonia, four or five ounces of sulphate of zinc, and cyanide of potassium, two ounces; these are to be added to six gallons of warm distilled water. **Walker** states that he tried this solution, but did not succeed.

The following solution of different metals is given on respectable authority as yielding a good bronze-colored deposit:—

50	parts carbonate of potassa,
2	„ chloride of copper,
4	„ sulphate of zinc,
25	„ nitrate of ammonia.

In operating with this liquid a brass plate is directed to be used as the positive electrode.

Laws of Deposit and Practical Instructions.—In coating articles with metals, it is important that the power of the battery should bear a certain proportion to the strength of the depositing liquid. The intensity of the apparatus may be raised by having a greater number of pairs, by using a less diluted acid, and by warming the electrolyte; the quantity of the electric current may be increased by lowering the zinc plates in the liquid. The opposite effects can be produced by a reversal of these conditions.

The quantity of metal deposited depends on the amount of the electric current passing through the solution, and, consequently, upon the size and number of the zinc plates in each cell of the battery, whilst its quality is regulated by the amount of the current passing compared with the size of the electrodes. The following may be given as the general laws of deposit, but different metals and different solutions vary so much that no positive relations can be fixed; only the general principles can be laid down. To obtain a bright crystalline deposit, a current of intensity and small amount is employed; for a hard and rather brittle reguline deposit, much force and moderate quantity; for a dark gritty powder, a strong and abundant stream; for an elastic and bright reguline precipitate, moderate intensity and small quantity; for a soft, tough, and perfectly reguline coating, a medium force and moderate quantity; for a soft dark powder, moderate intensity and large amount; for a soft sparkling film, low intensity and small quantity; for a tough reguline coating, low intensity and moderate quantity; and for an abundant soft black powder, low intensity and large quantity.

When the power of a battery decreases, a little acid may be added and the liquid stirred; but the better way is to substitute fresh acid. The solution in the battery should never be allowed to become thick or to crystalize. If any of the silver or copper plates of a battery, or any part of them, become covered with zinc, it is a proof that the acid is becoming exhausted.

Gore ascertained, in a long series of experiments, that the depositing power was almost invariably increased by keeping the dissolving metal hot, and the receiving article cold, by means of an appropriate apparatus. He also found that the opposite effects were produced by a *contrary* arrangement of the temperature. To insure perfect circulation of the current, care must be taken that the circuit is complete, that it is capable of conducting freely throughout, and that the various wires are perfectly clean at all their points of contact.

It may be proper to repeat here that in every case, to produce metallic deposition, there must be a complete circuit of substances: there must be a liquid in the circuit, the metal to be dissolved, and the article to be coated in that liquid, and to ascertain that this is complete, galvanometers are frequently used, particularly in cases of complicated apparatus.

Every large plating establishment has a number of stoneware pickling jars, pans, and vats of various sizes, called dipping jars, several large boilers of potassa liquid, various scratch brushes both for hand and lathe, and several washing troughs with a plentiful supply of clean water.

Mr. GORE gives the following rules for successfully working depositing liquids:—

Firstly, Avoid altering the composition or the proportion of the ingredients, except the water.

Secondly, Adapt the electric power to the liquid, that is, regulate the precipitation by alterations in the battery, rather than by any in the depositing vessel, except that the distance between the cathode and the anode may be altered, generally with advantage.

Thirdly, The dissolving metal as a general rule should be larger than the receiving article, which will have a tendency to strengthen the solution in metal.

The most philosophical position for the negative plate is the horizontal, but in practice this does not succeed, because the metals used for dissolving are never pure, and their impurities fall on the surface of the article; moreover, the operator cannot examine or remove it. The most practical position is the vertical, the dissolving metal and the receiving article being suspended in the menstruum facing each other, the latter being rather the lower of the two, and both wholly immersed, and the liquid being occasionally stirred to keep it uniform.

If the article to be coated has a very irregular outline, it is necessary to beat the dissolving plate somewhat to its form, so that the two may be nearly equidistant in their opposite parts, and thus a regular metallic deposit obtained. The nearer the receiving object is to the dissolving plate, the more rapid is the precipitation; and a large body of liquid deposits more rapidly and evenly than a small one.

For forming the connections, copper in wires or ribands is the most suitable, as it is one of the best conductors and not expensive. Large connecting-wires allow more copious precipitate than small ones. The article to be coated must be always connected with the zinc of the battery, and the metal to be dissolved with the copper or silver.

Precautions.—In some of the preceding operations, and especially in plating and gilding, the cyanide of potassium is employed. It is proper to state that this substance must be used with caution, both in handling the salt itself, and in breathing the cyanogen atmosphere which is exhaled from its solutions. When the operations are conducted in badly ventilated apartments, the workmen are often affected with giddiness and other distressing symptoms; and their hands are liable to ulceration, particularly if they have been immersed in the solutions. By exercising proper care, and avoiding to inhale the vapor of the cyanides, these inconveniences may be averted; and the other ingredients used in the different processes are not attended with danger. On the contrary, SMEE affirms, perhaps a little too strongly, that those conducting electro-metallurgical operations, generally fatten with their occupation, the minute quantities of sulphate of zinc and sulphuric acid which they imbibe, improving the tone of their stomach, helping digestion, and strengthening the whole frame. The salts of copper, he adds, have the same effects as those of zinc, but, perhaps, upon the whole, must not be made quite so free with. This is the testimony of a medical gentleman; but still, in these as in all other chemical operations, it is prudent to exercise a reasonable care in avoiding to inhale too freely any of the gases given off.

OTHER APPLICATIONS OF ELECTRO-METALLURGY.—It is manifest that the art of depositing metals from their solutions by galvanic agency, admits of a vast variety of applications. The more important of these have already been mentioned, but a few others will be briefly noticed.

Mr. RITCHIE has patented a method for extracting copper from its ores by the following process:—The calcined ore is dissolved in dilute sulphuric acid; this solution is put into a large vessel or trough, and a mixture of two parts water, and one of a saturated solution of sulphate of iron is poured upon it, taking care not to mix it with the lower liquid. An iron plate, as a generating metal, is then placed in the iron solution, and a plate of lead in the copper solution to receive the deposit. The voltaic arrangement is completed without a battery, by simply connecting the two plates by a wire. This process has never been put into practical operation.

NAPIER patented a method of coppering cloth by the electro-process, which forms in that case an excellent fire-proof covering for roofs, railway waggons, *et cetera;* but hitherto the article so manufactured has not succeeded in displacing the cheaper materials commonly employed for the same purpose. The cloth, being previously brushed over with a polish of black lead, and stretched upon a wooden frame surrounded with a copper band, is immersed in a large vat containing the cupreous solution. Battery power may then be applied, or a part of the vat may be partitioned off to receive the dilute acid and zinc. One pound of copper is found sufficient to communicate a perfect solid covering to twenty superficial feet of cloth.

Another method is to stretch the cloth upon a sheet of copper slightly curved, so that the cloth may be in close contact with it all over. The back or hollow side of the copper is then varnished, and a deposit formed by the battery process all over the front of the copper within the meshes of the cloth, and when sufficiently thick, the deposit and cloth firmly united together, may be drawn off the sheet of copper. Mr. J. SCHOTTLAENDER took out a patent, December 8, 1843, for depositing either plain or figured copper upon felted fabrics; he passes the cloth under a plain or engraved copper roller, black-leaded and horizontally immersed in a sulphate of copper solution; the copper is deposited upon the roller as it slowly revolves, and thus the meshes of the cloth are filled with metal, and the design of the roller copied upon it, and the coppered cloth slowly rolled off.

Cells for DANIELL's battery may be made by electro-deposition. For this purpose, coat the inside of a jelly-pot uniformly all over with wax or stearine, and then either brush it over with plumbago, or treat it with phosphorus, silver, and gold solutions; a connection should then be formed with the lower part of the coating, and the deposit effected either by the simple cell process, using the jelly-pot as the outer containing vessel, or by the battery process, using in either case, a sulphate of copper solution.

Hard copper dies may be formed from impressions on sealing-wax, gutta percha, or any other substance used for moulds. All embossed surfaces may be copied with facility, whether they consist of paper or any other material. If porous, they must be first rendered non-absorbent by oil, varnish, or wax, according to the thickness of the texture. Black-lead may be used to impart a conducting surface to seeds and roots, or other solid productions. But delicate leaves or flowers are prepared to receive the deposit by immersion in Mr. PARKES' solution, already described. Electro-coppered leaves, branches, and similar natural objects, are very beautiful. Even the delicate tendrils and hairs of plants may be all perfectly covered by this process. Insects may be coated or copied in the same manner. Every vegetal and animal substance whatever, which will remain undecomposed in the solution of copper for a few hours, can have a metallic mould made from it, or a metallic coating thrown over it.

But one of the most promising applications of the art is to the purpose of engraving and printing. This was the only application, indeed, which first occurred to its inventors, JACOBI, JORDAN, and SPENCER; and the art was pursued for some time with no other useful object in view. Hence its original name, the electrotype, which, although perfectly applicable when it was confined to the copying of objects, such as copper-plates, type, and medals, has long ceased to be appropriate, and does not embrace, in its etymological meaning, the far more important branch of the art, which consists in imparting to objects of use, or ornament, a permanent covering of gold, silver, copper, or some other metallic deposit. The word electrotype, in short, which, in accordance with its Greek origin, expresses the copying, moulding, or modelling of figures or characters by electricity, embraces only a part of the art, which, in its numerous modern applications, is more appropriately termed electro-metallurgy. This is the generic name for the whole. Electro-typing and electro-plating—using the latter term, as it ought to be used, with reference to all the metals, and not to silver alone—constitute its two leading divisions. There are, however, certain processes, such as the reduction of metals from their ores by voltaic agency, which, although correctly expressed by the general name, are contained within neither of these divisions.

One of the first objects pursued by SPENCER was to produce copies or fac-similes of common type, by the electro-process. This attempt was attended with very indifferent success; but, of late, a patent has been taken for a method of preparing stereotype plates, which promises to be of great value. This operation is performed on plates of the common stereotype metal, and consists in depositing a film of hard copper on the face of the letters. By this process, the plates are rendered much more durable, and yield a greater number of impressions without injury. A copper facing is given in the same manner to common type.

There is nothing to prevent forming the stereotype plate itself of deposited copper. A mould may be taken in the common way, either in paper or plaster of Paris, and this being saturated with oil or wax, and carefully covered with a film of black lead, or dipped into PARKES' patent solution, might receive a copper deposit of any thickness. The deposit being taken from the mould, and filled in with plaster of Paris, or gutta percha at the back, could be fixed to a block of wood or stereotype metal; but probably the trouble attending these operations would scarcely be compensated by any advantages gained. Instead of the paper or plaster, gutta percha, softened in boiling water, would form an excellent material for the mould, and would not require the preparation with oil or wax. DE LA RUE has been very successful in applying the electrotype process to many operations in ordinary printing. It has also been applied to plates for printing music, and for embossing soft materials, such as leather.

The multiplication of plain copper-plates, by this process, may seem to be a somewhat circuitous method of doing what is more easily effected by simple rolling and hammering. Yet, to make good copper-plates for engraving, is an operation attended with some difficulty; and those little cavities in the metal, which are found even in the best commercial copper, produce a degree of uncertainty in the engraving. These are avoided, and the process is much simplified, by depositing an electro-type plate on one of the prepared copper-plates. Deposited metal is always perfectly pure, and, by adjusting the power of the battery to the strength of the solution, may be made of any required solidity.

But a higher application of the art is to copy engraved copper-plates, which may be done with great nicety, producing a perfect fac-simile of the original. It matters not how complex the design, or how fine and delicate the execution—the engraved plate may be copied with the same ease and fidelity as the plain plate. The electrotype resembles the daguerreotype in showing its powers to the greatest advantage when it is employed in reproducing the most elaborate tracery. In applying the process, however, to engraved plates, on which the design is always in intaglio, the first electrotype plate that is deposited will be in relief. This plate must therefore be used as a mould for depositing upon it a second plate, which will be a fac-simile of the original. Another plan of forming the mould is to take an impression from the engraved plate, on a perfectly clean surface of lead, by means of a copper-plate press. To avoid the curling of the plate by the pressure, SMEE recommends that, when it is placed upon the lead, another plate be placed above it, before passing through the press. But very good moulds may be formed in white wax, or plaster of Paris, and, probably, still better, and more conveniently, in gutta percha.

The Art Union of London has employed this process to multiply copies of original plates, and it was found that the impressions taken from each electrotype varied from four hundred to one thousand, depending chiefly on the character of the engraving. The multiplication of engraved plates, in the same manner, is usefully carried out at the Ordnance Map Department at Southampton. Each copper-plate map, when finished by mechanical engraving, is transferred to the electrotype department, where any required number of duplicate plates are taken. Electro-metallurgy has, in this case, been of the utmost importance by enabling the Ordnance maps to be published at a moderate price.

The great demand for engraved copper-plates is at the potteries and calico-printing establishments. For use at the potteries, the device must be deeply cut in the copper, from which it is printed on a piece of thin paper, with a composition of arsenite of cobalt instead of the ordinary printer's ink. The paper is then pressed upon the pottery plate before it is glazed, in order that the ink may adhere to it, after which, the paper is washed off. Both the potters and the calico-printers chiefly employ the engraved plates in the form of cylindrical rollers—the plates, when engraved, being bent round into a cylindrical shape, and the edges soldered together. These copper-plates, before they are bent, may be easily multiplied by the electrotype process; but although active attempts were made so early as 1841, to apply the electro-deposition of copper to the preparation of the rollers in the first instance, both by depositing the copper upon wax, or other moulds, to make an entire roller of copper, or by depositing a surface of copper on iron or brass, the practical difficulties met with, in trying these applications, have hitherto been found insurmountable.

Woodcuts are easily multiplied by giving them a coating of black lead, and applying the ordinary process, first to produce a mould, and then a fac-simile in copper. Or a gutta percha impression may be employed with advantage for the mould in this, as in many other cases, for which its use is invaluable. But duplicates of woodcuts are so readily taken by the common stereotype process that this will continue to be generally preferred for common work. At the same time, for good engravings, the electrotype process is preferable. One of the most beautiful series of specimens of printing from electrotypes, is to be found in an illustrated edition of *Thomson's Seasons*, all the woodcuts of which were carefully preserved, and the actual printing performed from electrotype copies.

GLYPHOGRAPHY.—The most successful application of the electrotype to engraving is that mode of producing printing surfaces which has been termed by the patentee *Glyphography*. The following accurate account of the process is given in the last edition of SMEE'S admirable Elements of Electro-metallurgy :—

This branch of art was invented by Mr. E. PALMER; it forms an important feature for the general illustration of printed works, and on that account demands particular consideration. The term glyphography has been given by PALMER, to signify that the original drawing itself is at once engraved, requiring no copying, and in fact scarcely any instruments, except those with which the artist makes his design. The mode in which so extraordinary an end is accomplished appears ridiculously simple when it is detailed. The most essential part of the process is to make all the surfaces for printing as flat as possible, and for this purpose a plate of copper as used for engraving is first procured. This is blackened with the sulphide of potassium, in order that the draughtsman may be enabled to judge of the effect which his drawing would produce, as he proceeds with his work. This blackened plate is warmed, and then filmed with a compound of Burgundy pitch, white wax, rosin, spermaceti, and sulphate of lead, previously fused together. This composition, which is nearly white, must be uniformly spread over the plate, and the thickness should be about the one-thirtieth of an inch. The plate is now ready for the artist, who cuts through the white composition completely down to the blackened copper, and in fact, with the exception of that precaution, makes his drawing in the usual manner. In the selection of tools, the artist should be guided by the manner in which they can completely and clearly cut out the composition; for it is important to make a clear indentation, and not to turn aside the coating and leave a burr. A simple hook, fixed in a wooden handle, a hook filed away on one side, which most effectually cuts away the composition, or a piece of wood tapering to a fine point, are the forms particularly recommended by PALMER. The former instrument is best adapted for very fine lines, the second for larger, and the last for foliage and other free drawings and designs.

When the artist has finished his drawing, the parts of the composition which are removed leave black lines, which have precisely the same relation to the white ground as the black lines in the subsequent print have to the white paper; so that a most important feature in PALMER'S operation, is the exact similarity between the design and the print.

Many improvements have of late been made in the process; such, for instance, as giving a greater depth to the lights; for the ground through which the drawing is made being necessarily very thin, printers found great difficulty in keeping their work clean. To alleviate this, the plate is now submitted to the following process. A roller being made of glue and treacle, such as is used by printers for inking their work, is charged with a composition of gum—thus, turpentine, litharge, and red lead—and then passed lightly over the drawing, taking care that the roller is very lightly charged in the first instance, that it may not stop up the work. When this coat has become dry, which it will in a very short time if put on thin, the operation must be repeated again and again, until a considerable depth has been given to the work.

When this has been obtained for the general work, to the extent required, broad lights should be built up by means of brushes with the same composition, containing more litharge and sulphate of lead, or any other composition which will tend to aid the drying, and is not acted upon by the copper solution in the subsequent process. This part is very essential, or in printing, the paper is pressed to the bottom of what is intended to be a light, and the effect destroyed.

The operator must now allow the whole to get hard, and then with a magnifying glass go carefully over it, and remove anything which may have accidentally got into the lines. He must also then carefully brush it over with the best plumbago, taking great care to rub all out of the lines, or the block, after it is formed, prints rotten by the lines not being sound and firm.

The drawing is now ready to receive a deposit of copper, and the power of the battery must be carefully regulated to prevent too rapid a decomposition, or the copper is apt to grow over some parts if the line is not well cleaned out, and disappoint the artist by work not being copied, which he imagined he had put in.

Having obtained a sufficient thickness in the electrotype trough, and this must vary according to the size of the drawing, the deposited plate is separated, and the back trimmed to receive a layer of type metal, and then, having made the face perfectly flat, the back is turned off, and mounted upon a block of wood similar to a stereotype. Many touches, to relieve different parts, may then be readily put in by a person accustomed to use the graver; indeed, much time is saved by removing the composition altogether in some parts, and putting in any little touches afterwards to give relief to the darks.

The deepening of the work by the rolling process was a great improvement, by giving to the artist a plate with a much thinner ground than was at first used; but it was subsequently found by Mr. HAWKINS, who now carries on the process, that he could likewise form a block upon a common etching ground, which had been so much desired by those accustomed to etching; indeed, practice has now enabled him to form a surface block from almost any engraved plates.

Many very beautiful subjects have been done by this process. Some of the most successful are those well-known prints of the Bottle by CRUIKSHANK; but the subjects best adapted are maps, or writing of every description, and here it stands unrivalled both for price and quality.

There is another branch of art to be noticed, which is an invention called the electro-tint, and which may be dismissed in a very few words. A plain copper-plate is procured, upon which the artist makes a painting with some substance insoluble in the solution of sulphate of copper. The plate is placed in the solution and a reverse made, which is at once ready for the printer.

A great many specimens of the electro-tint have been published at different times, and of various degrees of excellence. Sometimes the electro-tint cast is used to print from the hollows, at others from the elevations; thus, in one case, it forms a kind of engraving, at another, a surface similar to that of a woodcut.—*Smee.*

Nature Printing.—One of the most beautiful applications of the Electrotype is to Nature-Printing—a method of producing impressions of plants, and other natural objects, in a manner so truthful, that only a close inspection reveals the fact of their being copies. So distinctly sensible to the touch are the impressions, that it is difficult to persuade those unacquainted with the manipulation, that they are the production of the printing press. The process, in its application to the reproduction of botanical objects, represents the size, form, and color of the plant, and all its most minute details, even to the smallest fibre of the roots. This art has been brought to great perfection, within the last few years, by Mr. HENRY BRADBURY, of the firm of BRADBURY and EVANS, who explained the history and details of the process in a lecture which was read before the Royal Institution in May, 1855; and from this lecture the following particulars are given.

The distinguishing feature of the process, compared with other modes of producing engraved surfaces for printing purposes, consists, firstly, in impressing natural objects—such as plants, mosses, sea-weeds, feathers, and embroideries—into plates of metal, causing, as it were, the objects to engrave themselves by pressure; and, secondly, in being able to take such casts or copies of the impressed plates as can be printed from at the ordinary copperplate press. This secures, on the one hand, a perfect representation of the characteristic outline of the plant, as well as that of some of the other external marks by which a plant is known, and even in some measure its structure, as for instance in the venation of ferns, and the leaves of flowering plants; and on the other hand, affords the means of multiplying copies in a quick and easy manner, at a trifling expense compared to the result obtained—and to an unlimited extent.

The great defect of all pictorial representations of botanical figures, has consisted in the inability of art to represent faithfully those minute peculiarities by which natural objects are often best distinguished. Nature-printing has, therefore, come to the aid of this branch of science in particular, whilst its future development promises facilities for copying other objects of nature, the reproduction of which it is impossible for the human hand to execute; and even were it possible, it would involve an amount of labor scarcely adequate to the results obtained.

Although considered for some years past in various parts of Europe as a new art, the idea, says Mr. BRADBURY, is by no means so recent as is supposed; much less is there ground for the Austrians to assert their exclusive right to the priority of the invention, merely on account of the first application of the process, in its fullest extent, in the Imperial Printing-office at Vienna. Nature-printing is nothing more than an application of facts worked out by various persons, in different countries, under very different circumstances, and at very different periods.

On account of the great expense attending the production of woodcuts of plants in early times, many naturalists suggested the possibility of making direct use of Nature as a copyist, and Nature herself, in her mysterious operations, seems to have given the first hint upon the subject in the beautiful and accurate impressions of ferns to be seen in the coal formations. In the Book of Art, by Alexis Pedemontanus, printed in the year 1572, and translated into German by WECKER, may be found the first recorded hint as to taking impressions of plants. At a later period—in the *Journal des Voyages*, by M. DE MONCOYS, in 1650, it is mentioned that one WILKENSTEIN, a Dane, gave instructions in making impressions of plants. The process adopted to produce such impressions at this period, consisted in laying out flat and drying the plants. By holding them over the smoke of a candle, or an oil lamp, they became blackened in an equal manner all over; and by being placed between two soft leaves of paper, and rubbed down with a smoothing-bone, the soot was imparted to the paper, and the impression of the veins and fibres was so transferred.

LINNÆUS, in his *Philosophia Botanica*, relates that in America, in 1707, one HESSEL made impressions of plants; and between 1728 and 1757, Professor KNIPHOF, at Erfurt, in conjunction with the bookseller FUNKE, established a printing-office for the purpose. He produced a work, entitled *Herbarium Vivum*, in twelve folio volumes, and containing one thousand two hundred plates. These impressions were obtained in a manner very similar to the method above mentioned, but with the substitution of printer's ink for lamp-black, and flat pressure for the smoothing-bone. A new feature at this time was introduced—that of coloring the impressions by hand, according to nature—a proceeding which, though certainly contributing to the beauty and fidelity of the effect, yet had the disadvantage of frequently rendering indistinct, and even sometimes totally obliterating, the tender structure and finer veins and fibres. Many persons at the time objected to the indistinctness of such representations, and the absence of the parts of fructification; but it was the decided opinion of LINNÆUS, that to obtain a fac-simile of the difference of species was sufficient.

SELIGMANN, an engraver at Nuremberg, in 1748, published in folio plates figures of several leaves he had reduced to skeletons. As he thought it impossible to make drawings sufficiently correct, he took impressions from the leaves in red ink, but no mention is made of the means he adopted. Of the greater part he gave two figures, one of the upper and another of the lower side. About the year 1790, HOPPE edited his Ectypa Plantarum Ratisbonensium, and also his Ectypa Plantarum Selectarum, the illustrations in which were produced in a manner similar to that employed by KNIPHOF. These impressions were found also to be durable, but still were defective. The production of impressions could only take place very slowly, as the blacking of the plants with the printer's ball required much time. Rude as the process was, and imperfect the result, it was nevertheless found that the figures thus produced were far more characteristic than any which artists could produce. The fault of the method consisted in its limited application and its incompleteness; since the fragile nature of the prepared plant, if ever so carefully treated, would admit of but very few copies being taken, and where any great number would have been required, many plants must have been prepared, a circumstance which was in itself a great obstacle.

In the early part of the present century, various improvements in the process were introduced, and at length, about the year 1830, the idea occurred of fixing an impression of the prepared plant in a plate of metal by pressure. It appears, on the authority of Professor THIELE, that PETER KYHL, a Danish goldsmith and engraver, established at Copenhagen, applied himself for a length of time to the ornamentation of articles in silver-ware, and the means he adopted were, taking copies of flat objects of nature and art in plates of metal by means of two steel rollers. Various productions in silver, by this process, were exposed in the Exhibition of Industry held at Charlottenburg, in May, 1833. In a manuscript, written by this Danish goldsmith, in May, 1833, is suggested the idea of applying this invention to the advancement of science in general. The plates accompanying this description represented printed copies of leaves, of linen and woven stuffs, of laces, of feathers, of birds, scales of fishes, and even of serpent skins.

The manuscript contains ample and clear instructions to carry out the method. He states, that to fix an impression into a plate of copper, zinc, tin, or lead, properly prepared for the purpose, a rolling machine with two polished cylinders of steel is required; if a *leaf*, quite dried and prepared, is placed between a polished steel plate half an inch thick, and a thoroughly heated lead plate with a fine surface, and these two plates with the leaf between be run speedily between the cylinders, the leaf will, by the pressure, yield its form on the softer lead plate, precisely as it is shaped, with all its natural raised and sunken parts. He adds, that leaves that are to be printed must first be spread upon a clean sheet of paper and placed upon a warm oven; a second sheet put over them is to be strewn over with sand, and the whole left to dry under a weight. This done, the leaves are taken out with due precaution, and placed for a quarter of an hour into water. They are dried again in the same way, and this manipulation is repeated four or five times. By this means he always found that the leaves gained in tenacity and firmness, that they lose all their moisture, and become more fit to be stamped. Objects, such as laces, weavings, figured ribbons, and such like, could be printed without any preparation, provided they were spread flat between the plates.

It would appear, says Mr. BRADBURY, from the practical hints here given, that PETER KYHL was no novice at the process. He distinctly points out what he conceives to be its value by the subjects which he tried to copy; and he enters into detail on the precautions to be observed in the operation of impressing metal plates so as to insure successful results. His manuscript explains that he had experimented with copper, zinc, tin, and lead plates. Still there existed obstacles which prevented him from making a practical application of his invention. In the case of zinc, tin, and copper, the plant, from the extreme hardness of the metals, was too much distorted and crushed; while in lead, though the impression was as perfect as could be, there were no means of printing many copies; as it was not possible, after the application of printer's ink, to retain the polished surface that had been imparted to the lead plate, or to cleanse it so thoroughly as to allow the printer to take impressions free from dirty stains. This was a serious obstacle, which was not compensated for even by the peculiar rich surface of the parts that were impressed, attributable to the lead being more granular than copper, and which is so favorable to adding density or body of color, without obliterating the tender veins and fibres. PETER KYHL died in the same year that he made known his invention. At his death, his manuscripts and drawings were deposited in the archives of the Imperial Academy of Copenhagen, where they remained for upwards of twenty years: and it is a remarkable fact, that, shortly after his death, was discovered the only thing wanting to render the process, as explained by him, at once available for practical purposes. Had **KYHL** lived to prosecute his experiments, he might have accomplished more than he did without requiring the aid of other means. It was he who discovered how to take impressions in metal plates, by using steel rollers.

This is the first element in the process of nature-printing. It fell to Dr. **FERGUSON BRANSON**, of Sheffield, to suggest the second, and the most important. In 1847, this gentleman commenced a series of experiments, an interesting paper upon which was read before the Society of Arts in 1851; and therein, for the first time, was suggested the application of the electrotype, which is now the most essential feature in nature-printing. Having taken in gutta-percha some impressions of ferns, the singularly beautiful manner in which the exact character of the plant was transferred to the gum, suggested to him the possibility of printing from the gutta-percha itself, so as to produce on paper a fac-simile of the plant. That experiment partially succeeded, and curiously tested the elasticity of the substance; for the impression remained uninjured, after being subjected to the great pressure of a copperplate roller. The printer, however, found it impossible so thoroughly to cleanse the ink from the margin around the impression, as not, when printed, to leave a dirty stain on the paper. The impressions thus produced were very accurate; but the process was valueless as regards multiplication of the prints. It then occurred to Dr. **BRANSON** that an electrotype copy would obviate the difficulty.

He afterwards stated that he abandoned the process of electrotyping in consequence of his finding it tedious, troublesome, and costly to produce large plates. Having occasion, however, to get an article cast in brass, he was astonished at the beautiful manner in which the form of the model was reproduced in the metal. He determined, therefore, to have a cast taken in brass from a gutta-percha mould of ferns, and was much gratified to see the impression rendered almost as minutely as by the electrotype process; but, however curious his individual specimens, the process produced no practical result.

In 1849, Professor **LEYDOLT**, of the Imperial Polytechnic Institute at Vienna, availed himself of the resources of the Imperial Printing-office to carry into execution a new method he had conceived of representing agates, and other quartzoze minerals, in a manner true to nature. This able philosopher had occupied himself for a considerable period in examining the origin and composition of these interesting mineralogical objects. In the course of his experiments and investigations, he had occasion to expose them to the action of hydrofluoric acid, when he found, in the case of an agate, that many of the concentric scales were totally unchanged, while others, to a great extent decomposed by the acid, appeared as hollows between the unaltered scales. It occurred to **LEYDOLT** that the surfaces of bodies thus corroded might be printed from, and copies multiplied with the greatest facility.

The simplest mode for obtaining printed copies is to take an impression direct from the stone itself. The surface, after having been etched, is well washed with dilute hydrochloric acid, and dried; then carefully blackened with printer's ink. By placing a leaf of paper upon it—*India paper* and *Chalk paper* are the best adapted for the purpose—and by pressing it down upon every portion of the etched or corroded surface with a burnisher, an impression is obtained, representing the crystallized rhomboidal quartz *black*, and the weaker parts, that have been decomposed by the action of the acid, *white*. It requires but a small quantity of ink—and particular care must be exercised in the rubbing down of the impression. This mode is good as far as it goes—but it is slow and uncertain—and incurring a certain amount of risk, owing to the brittle nature of the object; and the effect produced is not altogether correct, since it represents those portions black that should be white, and *vice versâ*.

The stone is not sufficiently strong to be subjected to the action of a printing press; an exact fac-simile cast of it must, therefore, be obtained, and in such a form as can be printed from. To effect this, the surface of any such stone, previously etched by corrosion, must be extended by imbedding it in any plastic composition that will yield a perfectly flat and smooth surface, so that the surrounding surface of the plastic composition will be exactly level with the surface of the etched stone: all that is necessary now, is to prepare it for the electrotype apparatus, by which a perfect fac-simile is produced, representing the agate impressed, as it were, into a polished plate of copper. This forms the printing plate. The ink in this case, as opposed to the mode before referred to, is not applied upon the surface, but in the depressions caused by the action of the acid on the weaker parts; the paper is forced into these depressions in the operation of printing, which results in producing an impression in relief—a feature that is rather peculiar to the process, as the raised appearance, especially in the case of plants, adds very much to their effect. The impressions printed in this latter manner present far more beautiful and natural representations, since the crystallized quartz portions are represented *white*, while the decomposed parts appear *black*.

Professor **LEYDOLT**, however, suggests that some corroded stones are better suited sometimes for one method of representation than the other; and attention should be paid to this while the stones are being exposed to the action of the acid. He considers that important advantages will result to science from the perfect faithfulness of such representations, and from the facility and inconsiderable expense of their production.

Other objects in geology—such as the fossil remains of fishes, plants, *et cetera*—can in some cases be copied with remarkable resemblance to the original. In operating upon this class of objects, it is desirable that the original should be as flat as possible, as the smoother the general surface is, the more successful will be the effect produced. A mould in the first place is taken with gelatine or liquid gutta-percha, the elasticity of which materials are favorable for flattening the mould without distortion when separated from the original—a mode that is to be preferred to depositing copper direct upon them, since it is very much more easily manipulated, and without the slightest risk of damaging the originals, owing to the absence of pressure. This gelatin or gutta-percha mould is rendered metallic or conducting in the usual way by the application of plumbago, and copper is deposited until of sufficient thickness to form a printing plate.

In 1852, Mr. AITKEN, of Birmingham, followed the footsteps of KYHL in various experiments made by him in Britannia metal. He took impressions of lace, skeleton-leaves, feathers, and other objects in this metal, for the purpose of ornamentation, in the same way as KYHL is said to have done in articles of silver. About this period Dr. BRANSON again made experiments, and endeavored to bring nature-printing into practical operation. He too tried impressions on Britannia metal, not altogether with the view of printing direct from such plates, desirable as it would be to dispense with the operation of taking casts—but of transferring impressions to stone; and after printing an impression in some neutral tint, to resort to coloring by hand.

In the Imperial Printing-office of Vienna, the first application of taking impressions of lace on plates of metal, by means of rollers, took place in the month of May, 1852: it originated in the Minister of the Interior, BAUMGARTNER, having received specimens from London, which so much attracted the attention of the Chief Director, that he determined to produce others like them. This led to their employing gutta-percha in the same manner that BRANSON had used it; but finding this material did not possess altogether the necessary properties, the experience of ANDREW WORRING, the superintendent of the printing establishment, induced him to substitute lead, which was attended with remarkable success. Professor HAIDINGER, on seeing specimens of these laces, and learning the means by which they had been obtained, proposed the application of the process to plants. The results of these experiments, which consisted of specimens of lace, leaves, plants, mosses, serpent-skins, the wing of a bat, agates, fossils, and petrifactions, as well as those of Professor LEYDOLT above referred to, appeared in the fifth volume of Memoirs of the Imperial Academy, published at Vienna, in 1850.

Up to this time, however, in England, notwithstanding the above-mentioned experiments, the discovery had not assumed any practical form. Nature-printing owes its present success to the electrotype, which was then, and even at the present time is, the only means by which faithful copies can be taken of those delicate fibrous details that are furnished in the examples of the impressions of botanical and other figures in metal. It may be said to be owing to the extensive scale upon which the process of the electrotype is conducted in the Imperial establishment, that WORRING was enabled to render the process of nature-printing practically available as a Printing Art, and that which was done for it by WORRING in Germany, Mr. BRADBURY has accomplished in England.

The mode of printing the electrotype plates of plants, is the same as in ordinary copperplate printing, where the impression is produced by passing the inked plate, with the sheet of paper laid upon it, through a pair of rollers, one of which is covered with four or five thicknesses of blanketing, which causes the peculiar raised or embossed appearance of the impression.

In such cases, where there are three, four, or more colors, for instance,—as in flowering plants, having stems, roots, leaves, and flowers,—the plan adopted in the inking of the plate, is to apply the darkest hue first, which generally happens to be the roots—the superfluous color is cleaned off—the next darkest shade, such as perhaps the color of the stems, is then applied —the superfluous color of which is also cleaned off: this mode is continued until every part of the plant in the copperplate has received its right tint. In this state, before the plate is printed, the colors in the different parts of the copper look as if the plant was imbedded in copper. By putting the darkest color in at the beginning, there is less chance of smearing the lighter ones: the printer, too, is not only able, by this means, to blend one shade into another, but to print all the colors at one single impression.

The *first* practical application of nature-printing for illustrating a botanical work, and which has been attended with considerable success, is CHEVALIER VON HEUFLER'S work on the Mosses, collected from the Valley of Arpasch, in Transylvania; the *second—the first in this country*—is the *Ferns of Great Britain and Ireland* in course of publication, under the editorship of Dr. LINDLEY, and printed by Messrs. BRADBURY and EVANS. Ferns, by their peculiar structure and general flatness, are especially adapted to develop the capabilities of the process, and there is no race of plants for which minute accuracy in delineation is of more vital importance than the ferns; in the distinction of which, the form of indentations, the general outline, the exact manner in which repeated subdivision is effected, and most especially the distribution of veins scarcely visible to the naked eye, play the most important part. To express such facts with the necessary accuracy, the art of a DAGUERRE or a TALBOT would have been insufficient until nature-printing was brought to its present state of perfection.

COPYING DAGUERREOTYPE PICTURES.—The triumph of the electrotype, properly so called, or one at least of the most beautiful applications of the electro-deposition of copper, is that of copying daguerreotype pictures; the process, moreover, is perfectly simple, and is thus minutely described by Mr. GORE, with a remarkable observation made by himself on the subject:—Solder a wire to one corner of the back of the picture, then varnish the back and edges and let them dry, hang it in a perfectly clean sulphate of copper solution—one free from dust on its surface—and connect it with one or two pairs of small SMEE'S batteries; in the course of twenty or twenty-four hours, when the deposit is sufficiently thick to remove, take it out, well wash it, and wipe it perfectly dry, then with a strong pair of scissors cut off the edges all round; the original and copy may then easily be separated by inserting the point of a knife or the end of a thin wedge of hard wood between them at the edges. If the process has been carefully conducted, and the original picture is a strong one, a most beautiful and vivid copy will be obtained; a number of copies may be taken from the same original, especially if it is a strong one, and has been well fixed by FIZEAU'S process; but the intensity of the copies and of the original appears gradually to diminish in each succeeding trial.

Under such circumstances, especially with very regular action of the battery, a fine deposit, clear solution, and vivid original picture, **GORE** observed a most extraordinary effect, namely, that the picture had not disappeared, even in twenty-four hours, although the deposit upon the original plate had constantly increased in thickness, but had penetrated quite through the deposit, and appeared distinctly upon the back. **GORE** has remarked the image repeatedly on the back as well as upon the front of deposits as thick as an address card. Sometimes the image was optically positive, and sometimes negative.

UTILITY OF ELECTRO-METALLURGY.—The different cases in which electro-metallurgy is serviceable for the various departments of printing have been now described, and extensive as are their present applications, doubtless there is still much to be effected in this department alone.

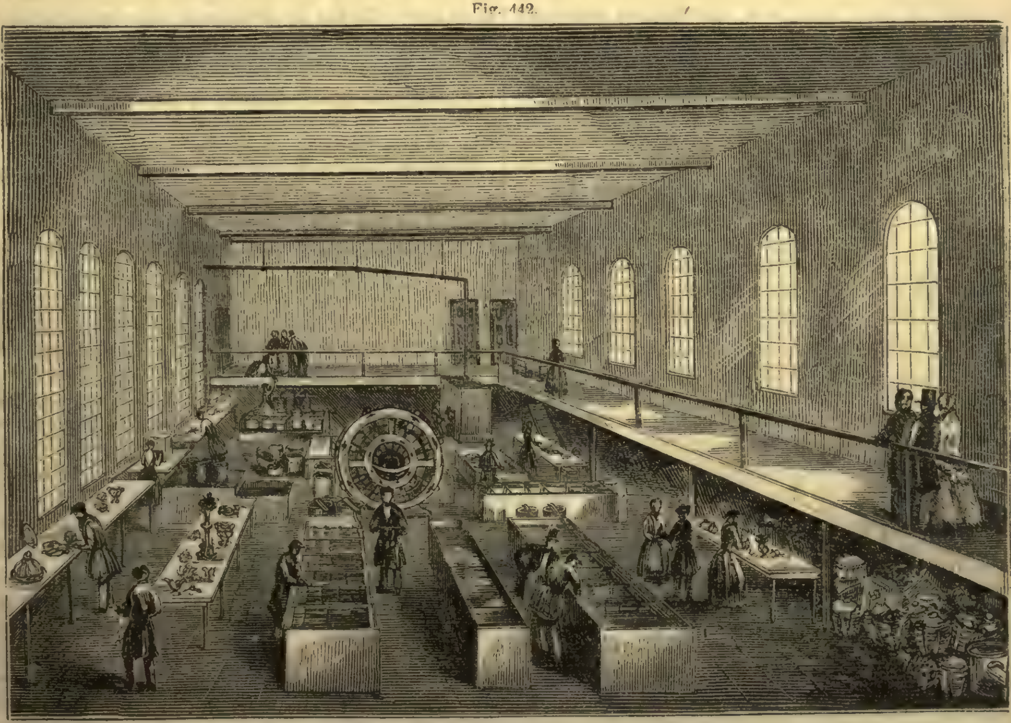
The same may be affirmed of its application to the arts in general. It may, indeed, says **SMEE**, be a matter of conjecture to what extent this science may be ultimately carried out, or to what other purposes it may be applied in years to come, but were it never to be directed otherwise than it has already been, were it to stop for ever at the point to which it has now been brought, no one can deny that it is a most valuable acquisition; in short, one may safely assert that no other discovery ever presented capabilities at once so many, so various, so interesting, or so valuable.

Doubtless the galvanic fluid will, before long, be as important to the manufacturer as the heat of a furnace. Now-a-days, a person may enter a room by a door having finger-plates of the most costly device made by the agency of the electric fluid; the walls of the apartment may be covered with engravings, printed from plates originally etched by galvanism, and multiplied by the same force; the chimney piece may be decked with ornaments made in a similar manner. At dinner, the plates may have devices given by electrotype engravings, the salt spoons gilt by the galvanic fluid, and the table decorated with costly electro-silver-plated objects. All these, and many other applications, there are at present, but one must still look forward to the most important properties of the electric current derived from the galvanic battery; for although great and glorious are the triumphs of science detailed in this work, yet the prospect of obtaining a power which shall supersede steam, exceeds in value all these appliances. For to cross the seas, to traverse the roads, and to work machinery by galvanism, or rather electro-magnetism, will certainly, if executed, be the most noble achievement ever performed by man.

Those who are, comparatively, unacquainted with electricity and galvanic apparatus, may meet with some little trouble in entering upon the science of electro-metallurgy; but commencing upon a right method, their first trouble will be their last; and let them always bear in mind, that without trouble no great good was ever accomplished.—*Smee.*

STATISTICS.—Birmingham has always been the chief seat of the electro-plating and gilding trade, by which a complete revolution has been effected in the art of coating with metals. It was introduced by Mr. **ELKINGTON** in 1840, amidst much discouragement and opposition. Manufacturers and retail tradesmen were alike opposed to the change. All sorts of objections,

Fig. 442.



writes a correspondent of the *Morning Chronicle*, were started, and the silversmiths refused in many instances to take the articles into their shops, *even to retail them at a profit.* But these and innumerable other difficulties were ultimately powerless to obstruct the progress of art. The wonderful nature of the agency by which the result was effected excited curiosity; but when it was seen that the operation was so simple and so unerring, that the most elaborate articles could be plated with as much perfection as a common sheet of metal, and that for beauty and elegance, electro-plated goods were fully equal to objects chased in solid silver or gold, a demand for them began to arise. As early as the year 1841 the business had assumed great importance, and in 1842, the Messrs. ELKINGTON found constant employment for as many as three hundred persons. The manufacture has since gone on increasing, and the patentees now employ seven hundred people. The annexed engraving—Fig. 442—will convey an idea of the interior arrangements of this extensive factory, of which it is an accurate delineation.

The principal advantages of the electro-plated goods are, that they are manufactured in the same manner as silver, the ornamental parts being chased in solid metal; that, where joints are necessary, none but hard solder is used; that the base is composed of a purified white nickel metal of great durability, and of the same color as the exterior; that the union of the surface and base is perfect, forming one body; that the plating on the more prominent parts is, from the nature of the process, stronger than on those less exposed to wear; that every description of style, however elaborate, and whether embossed or engraved, can be plated with the same facility as a plain surface; that with moderate care these goods will last from ten to twenty years, and that they can be replated when injured or worn—which, under the old processes, could not be done—at a comparatively trifling expense.

The show rooms of Messrs. ELKINGTON and MASON contain specimens not only of electro-plated articles, such as *épergnes*, candlesticks, candelabra, bronze statues and statuettes, vases, and countless other objects of domestic use and adornment, of modern and of antique art, but of new adaptations of the electro-process to the service of the sciences. They exhibit beautiful specimens of the vegetation or growth of copper by electrical agency; of iron coated with zinc or copper; of flowers and shrubs, with all their delicate anatomy and tracery, covered with metal, and thereby rendered imperishable; and of birds and insects coated and preserved by the same wonderful but simple means. Leaves and flowers of gold and silver are thus manufactured, nature being made to form the basis of art in a manner hitherto unknown. Flowers and shrubs, insects, and other natural objects which it is wished to preserve, are coated with zinc, copper, silver, or gold. Where the filming is of the less valuable metals, it may be painted of the color of nature; and the specimens in this way may be preserved for centuries. So delicate is the operation of the electric current, that even a spider's web may be plated with gold or silver. The Editor, in inspecting this establishment, was greatly struck with different kinds of plotting scales, in the centre of which were embedded beautiful bronze reliefs. The workmen employed are, as might be expected, of a superior class.

ENAMELS.—*Email*, French; *Schmelzglas*, German; *Encausti*, Latin.—Enamels are substances of the nature of glass, differing from it, however, by a greater degree of fusibility or opacity. They are colored by different metallic oxides, to which certain persistent fusible salts are added, such as the borates, fluorides, phosphates, *et cetera.*

The ancients carried the art of enamelling to a very high degree of perfection, and beautiful specimens of their ingenuity are occasionally found, of which neither the composition nor the mode of applying it is known. Then, as at present, each artizan made a mystery of the means that succeeded best with him, and thus a great number of curious processes have been buried with their originator. Another cause, says URE, contributes powerfully to this kind of declension in the arts. Among the vast numbers of prescriptions which have been given or published for the formation of enamels, there are several in which substances are mentioned that can no longer be procured, whether owing to a change of denomination, or because they cannot now be found in commerce, or else they are not of the same nature as of old. Hence, in numerous instances, it is found impossible to obtain satisfactory results. Owing to this, it is desirable that new investigations should be undertaken, and for these, *raw materials of the purest kind* selected. Dr. LEWIS states that he once produced an enamel of a beautiful color, but he was unable to succeed a second time, though he took infinite pains, and tried a multitude of experiments. This certainly must have been owing to his not noting the proportions of the ingredients in the first assay, or else to his not being able to obtain them in the same state. It is a fact, that an additional quantity of a metallic oxide, beyond a certain limit, instead of deepening the color, actually destroys it; further, the degree of heat to which a mixture is subjected often militates against the desired result.

A singular circumstance may be here noticed, which is, that a vitreous mass containing copper, when removed from the melting pot, sometimes only exhibits a faint greenish hue; still, in this state, nothing more than simple exposure to a gentle heat is requisite to throw out a brilliant red.

This alteration in color is very curious. It may consist in the proneness of the copper to pass from the state of suboxide—Cu_2O—into that of protoxide—CuO—by the absorption of oxygen,

$$Cu_2O + O = 2\,CuO,$$

which tinges glass green; but for this to occur at so incipient a temperature is remarkable.

Glass containing gold exhibits the same singular change of tint under similar circumstances.

M. SPLITTBERGER displayed specimens of glass ten years ago, into the composition of which gold entered as a chloride. They were white, but when re-heated in the flame of a spirit lamp, they assumed a deep-red tinge. If, again, this red glass be subjected to the heat of an oxygen blowpipe, it loses nearly all its color.

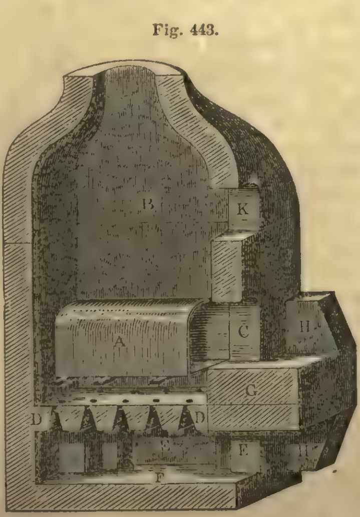
These metamorphoses have been vaguely attributed to different degrees of oxidation in the metal; but if this be the case, it is strange that mere exposure to a slight temperature can effect any chemical variation in the interior of a solid mass of glass, which has already undergone a heat far more intense. **Beckmann** found that metallic gold gives the red color as well as its oxide, and it appears scarcely to admit of a doubt, that in a metal so easily reduced, the whole of the oxygen must be expelled long before the enamel has reached its melting point. It has for many years been known that silver imparts a color to glass while in the state of metal, and everything leads one to suppose that the case is the same with gold.

The material employed of old to tinge glass red was the suboxide of copper; but on the discontinuance of the art of glass-painting the dependent manufacture of ruby glass of course ceased, and the process became so entirely extinct, that the idea generally prevailed that the color in question was derived from gold. In 1793, the French government actually collected a quantity of ancient glass with the view of extracting the gold by which it was supposed to be tinged. It is remarkable that the knowledge of the copper-red should have been so completely lost, though printed receipts have always existed detailing the whole method. **Baptista Porta** gives a recipe, noticing at the same time the difficulty of following it. **Kunkel** discovered that gold, when melted with flint glass, imparted a fine ruby tint; and the fact that he derived great profit from this invention, was the cause of his being so reticent upon the subject, while his successors have kept the secret of his method as much as possible inviolate to the present day.

The Venetians are still in the possession of the best processes, and they supply the French and other nations with the finest kind of enamel.

Before entering upon the different varieties of enamels, it is desirable to describe the furnace in which they are fabricated. The enamel furnace is represented in Fig. 443. The burning is effected in a muffle, A, a thin clay vessel heated from without, the interior of which is nowhere in connection with the fire-place, B, of the furnace, and the mouth of the muffle fitting exactly the aperture, C. The pierced plate of clay, D D, answers the purpose of a grate, and is supplied with air by three apertures, E E, of the ash-pit, F. A ledge, G, is erected for convenience before the working-hole, C, and is supported by the checks, H H. The aperture, K, is for the purpose of stirring the fire, and can be closed like any one of the others by a clay door.

Fig. 443.



Before the work is begun, the furnace must be made red-hot; the pieces are then inserted, and the aperture, C, is closed in such a manner as to leave a small crack, through which the fusion can be watched. The success of the enamelling process depends upon a proper mean being maintained between that temperature which would cause the enamel to flow, and that at which it only imperfectly softens and its surface remains rough. The most common defect in the appearance of enamelled articles is caused, however, by air-bubbles, which have not found an opportunity of fully effecting their escape. These either occasion a protuberance, or, when they have burst, a concavity, which frequently render it necessary, subsequently, to give a finish to the piece.—*Knapp.*

Enamels are distinguished into transparent and opaque; in the former, all the elements have experienced an equal degree of liquefaction, and are thus run into crystal glass; whilst, in the others, some of them have better resisted the action of heat, so that their particles retain sufficient aggregation to prevent the transmission of light. This effect is produced particularly by the oxide of tin, as will be perceived when treating of white enamel. The frits of enamels that are to be applied to metallic surfaces require greater fusibility, and should, therefore, contain more flux; and the sand used for these should be calcined beforehand with one-fourth its weight of chloride of sodium; sometimes, indeed, metallic fluxes are added, as minium or litharge. For some metallic colors the oxides of lead are very injurious; in such a case, recourse must be had to other fluxes.

The following mixtures have been found serviceable for purples, blues, and some other delicate colors:—

Three parts of silicious sand, one of chalk, and three of calcined borax; or, three of glass—of broken crystal vessels—one of calcined borax, one-fourth of a part of nitrate of soda, one part of well-washed antimoniate of potassa. These compositions afford a very white enamel, which accords perfectly well with blue.

It is obvious that the composition of this primary matter may be greatly varied; but one should never lose sight of the essential quality of a good enamel, which is, to acquire, at a moderate heat, sufficient fluidity to take a shining surface without running too thin. It is not perfect fusion that is wanted, but a pasty state, of such a degree as may give it, after cooling, the aspect of having suffered complete liquefaction.

Dead-white Enamel.—Greater nicety is necessary in the choice of its materials than any other, hence the frit employed in this case should be itself composed of *perfectly pure ingredients.* But a frit should not be rejected hastily because it may be somewhat discolored, since this may depend upon two causes—either on some metallic oxides, or on fuliginous particles proceeding from vegetal or animal substances. Now, the latter impurities may be easily removed by means of small quantities of binoxide of manganese, which has the property of readily parting with a portion of its oxygen, and of thus facilitating the combustion—that is to say, the destruction—of the coloring carbonaceous matter. Manganese, indeed, possesses a tinctorial power itself on glass, but only in a very high state of oxidation, and when reduced to the lower state, as is done by incombustible matters, it no longer tinges enamel combinations. Hence the proportion of manganese should never exceed what is requisite; for any surplus would cause color. Sometimes, indeed, it becomes necessary to give a little manganese tinge in order to obtain a more agreeable shade of white, as a little azure blue is added to linens to brighten or counteract the dullness of their yellow tint.

A white enamel may be conveniently prepared also with a mixture, composed of two parts of tin and one of lead calcined together; of this combined oxide, one part is melted with two parts of fine crystal and a very little manganese, all previously ground together. When the fusion is complete, the vitreous matter is to be poured into clear water, and the frit is then dried and remelted. The pouring into water and fusion are sometimes repeated four times, in order to secure a very uniform combination. The crucible must be carefully screened from smoke or flame. The smallest portions of oxide of iron or copper admitted into this enamel will destroy its value.

Some practitioners recommend the use of the washed alkaline antimoniate for white enamel; but this product cannot be added to any preparation of lead or other metallic oxides; for it would tend rather to tarnish the color than to clean it up, and it can be used, therefore, only with ordinary glass or with saline fluxes. For three parts of white glass, without lead, one part of washed antimoniate of potassa is to be taken; the substances are well ground together, and fused in the common way.

CLOUET has written the best paper upon enamels, and the Editor, therefore, translates much of the interesting matter contained in it relative to their composition, *et cetera.*

WHITE ENAMEL.—This enamel, either for earthenware or for applying on metals, is composed as follows: A mixture of lead and tin is calcined, which may vary in the following proportions—namely, for one hundred parts of lead, fifteen, twenty, thirty, and even forty of tin. The mixture of these two metals calcines readily with the contact of air. As soon as this alloy is heated to the point of incipient redness, it burns like charcoal, and calcines very fast. The best quantities are those which, for one hundred of lead, contain twenty to twenty-five of tin. In proportion as the calcination is effected, the heated part is withdrawn, and the rest is continued to be oxidized till the whole becomes pulverulent. As some small grains always escape, the oxide obtained is passed a second time into the fire in order to heat it completely, which is known to be the case when it no longer sparkles—that is to say, when one no longer observes parts which burn like coals, and the whole appears of one uniform color.

When the proportion of tin exceeds twenty-five or thirty, a stronger fire is required. However, by varying the power of the fire, one may ascertain that which suits best for the bodies operated upon. One hundred parts of the above mixture are usually taken, and the same of sand. Twenty-five to thirty pounds of chloride of sodium are now to be added, the whole well rubbed together, and the mixture put to melt on the furnace in which the ware is baked. This article is usually placed in sand, or lime slaked in the air, or on ashes.

The lower part of the mass is pretty generally not well melted. Nevertheless, this does not prevent the substance, when brayed and afterwards put in the goods, becoming very white in baking in the furnace. When withdrawn from under the furnace it is not white; it is often even rather black; usually, it is marbled a black, grey, and white.

This method of procedure is that which is practised in the potteries. In the compositions intended for such works, the proportion of twenty-five of tin to one hundred of lead is scarcely exceeded; even for common earthenware, potters are satisfied with fifteen of tin to one hundred of lead.

It is obvious that, if it be wished to obtain a whiter and more fusible enamel, the quantity of sand must be diminished, while that of the chloride of sodium must be increased; as the whiteness and opacity depend on the quantity of tin, twenty-five or thirty of the *calcine* may be taken to one hundred parts. For example, one hundred of the mixture, sixty of sand, and twenty-five of metallic chloride, give a very fusible composition.

But it is to be observed that some further manipulations must be practised when enamels are to be obtained fit for being laid on metals, and to have them in full perfection.

In that case, crude sand is not used; it is calcined with one-fourth of its weight of chloride of sodium over a strong fire, either on the small scale in a crucible, or on the large under a furnace; further, if a very fusible enamel is desired, it is mixed with minium or with lead calcined in this first operation, nearly in the same proportion as with salt—that is to say, one-fourth; a white mass is then obtained, half-melted and porous, which is pulverized, and is used in the composition of the enamel instead of the sand. This substance may even be diminished to fifty per cent. if a very fusible enamel is desired. It depends also on the kind of *calcine* employed; for that which contains most tin is least fusible.

When fluxes for the colors are required, the same compositions above mentioned are used, except that little or no tin is put in the lead. In the latter case, minium is usually taken. This flux is good for certain colors, but not for all. It is found that fluxes into which oxides of lead enter, tarnish; in that case, other fluxes are formed without oxide of lead; nitrate of soda and borax are usually employed to make these glasses; no calcine of tin is used. The following results were found by CLOUET:—Three parts of silicious sand, one of chalk, three of calcined borax, give a substance suitable to serve as a flux for purples, blues, and other delicate colors; three of white *gobleterie*, one of calcined borax, one-fourth part of nitrate of soda, one part of white oxide of antimony made with well-washed nitrate of soda, yield a very white enamel, which may serve also as a flux for purple, and especially for blue.

Sixty parts of enamel sand, or less, thirty of alum, thirty-five of chloride of sodium, and one hundred of minium, or other oxide of lead, yield a white enamel when the fluxes do not predominate too much; and a gelatinous glass when the latter are in large quantity. This glass is good for red, and the enamel does for all clays, or earths, which can stand a strong fire.

It is very important to observe, and to be aware of the fact, that the sand which is used for enamels is not that which contains only silicic acid—this is worth nothing—it must be a sand having also talc.

It requires nearly one part of talc to three of silicious sand to make enamels, and color fluxes, *et cetera.*

What appears to be most essential for the success of enamels is the choice of the sand. It is very possible to compose the sand by art. Although CLOUET did not decompose it, he found by synthesis that three parts of suitable sand and one part of talc were very good for enamels; hence it is obvious that one requires only a good analysis of the talc to be able to compose the mixture easily. This sand will be procured in places where earthenware is made. It is easily known; independently of the silica which constitutes the greater part of it, talcky particles are found in it in great quantity, and, to be good, it must involve about one-fourth; when it does not contain enough, the enamel which it produces is more difficult to melt, and does not become smooth; it remains grainy, and makes what is called *egg-shell.* Combinations of earth certainly exist capable of producing very good fluxes either for enamels or for transparent colors. It would be desirable to try these combinations. Heavy spar—sulphate of baryta—and lime melt very well together. By adding a little silica and a little magnesia, it is probable that one would produce a very good substance. If this glass, composed of lime and baryta only, were solid enough to resist the air and weak acids, one would not require to add silica to it; but if, as CLOUET thinks, chloride of sodium must also enter into the composition of these glasses, then silica must be there also. One might vary experiments on the subject. When glasses destined for color fluxes are employed, it is customary, in order to render them still more fusible, to add to them a little nitrate of soda and borax.

It is essential that the lead and tin destined to make the oxide for producing the white enamel be melted and mixed together before being calcined; and if it be desired that the enamel have all its whiteness immediately, it is good that this calcination should be very complete.

CLOUET suggests that bismuth might be substituted for the lead. This alloy would give a good product. Bismuth might also be added with lead, making the following mixture—namely, one part of lead, one of bismuth, one of tin, or using other proportions.

The principal characteristic of a good enamel, and which renders it fitted to be laid on baked clays, earths, or metals, is its facility in glazing with a moderate fire—a cherry-red heat, or a little more or less, according to the nature of the enamel—without entering into complete fusion. These are the qualities possessed by enamels which are applied on pottery or earthenware articles. They do not enter into complete fusion, otherwise they fail; they take only a pasty state—indeed, a very firm paste; and yet, when they are baked, one would say they had been completely melted.

There are two modes of painting on enamels—on the crude, or on the baked. One employs, or may employ, for the same object both of these methods. Solid colors may be laid on which can stand the fire necessary for baking, in melting the crude enamel, and afterwards finish with delicate colors. The hues which are laid on the crude enamel do not require a flux; there is one, however, to which silica must be added—namely, the calcine of copper, which gives a very fine green; but when it is wished to employ it on the crude enamel, it must be mixed with about two parts by weight of silica, and the heat raised till the mixture enters into combination. The mass obtained is afterwards pulverized for use.

It is also essential, in order to have the enamel very white, to make sure of the purity of the lead and tin. If these metals contain copper or antimony, as pretty often happens, the enamel will not be fine. Iron is less hurtful.

COLORED ENAMELS.—All the colors are produced with metallic oxides. These are more or less fixed in the fire, according as they hold more or less strongly to their oxygen; thus, all the metals which easily lose this element cannot stand a great degree of heat, and cannot be employed on the crude enamel.

Purple.—This color is oxide of gold, which can be prepared in different manners, either by precipitating with tin, or by the chloride of tin, a solution of gold much diluted with water. One must put only as little as possible of the stannic solution to form this deposit; it is added gradually till the purplish color appears, then no more is added, and the color is left to deposit, and afterwards poured into a glass vessel to dry it slowly. The different solutions of gold, in whatever manner precipitated, provided the gold is thrown down in the state of oxide, give always a purple hue—so much the finer the purer the oxide; however, neither the copper nor the silver, which usually exist alloyed with the gold, spoil this tint very perceptibly. Iron changes it; but the precipitate of gold which gives the finest purple is, without contradiction, fulminating gold, which loses this property when it is mixed with fluxes. Purple is a powerful color; it can bear much flux, and in small quantity imparts its color to much matter.

It appears that the saline fluxes agree better with it than those into which the metallic calcines enter; thus it will be necessary to give it those which are made with silica, carbonate of lime, and borax; or white glass, borax, a little white oxide of antimony, and nitrate of soda. Purple can bear, or carry, from four to twenty parts, and even more, of flux, according to the shade desired. Painters on enamels usually employ for purple a flux which they name *brilliant white*; this appears to be a semi-opaque white enamel, which is put on tubes, and afterwards blown into bulbs at the enameller's lamp. These bulbs are afterwards broken, so that this flux is found in commerce in small scales, which have the appearance of *debris* of minute hollow spheres. Painters in enamel mix this flux with a little nitrate of soda and borax. Purple does not stand a strong fire.

Red.—There is no metallic oxide which yields directly a melted red—that is to say, no metallic calcine, entering into fusion, and combining in the form of transparent glass with the fluxes of glasses, gives directly a red color; to obtain this, it must be compounded of different substances in the following manner:—Two, or two and a half, parts are taken—or even one may be sufficient—of sulphate of iron, and one of sulphate of alumina; they are melted together in their water of crystallization, and care is taken to mix them well; they are heated to perfect dryness; the fire is then increased till the mixture becomes red. This last operation should be performed in a reverberatory furnace. The red mixture is kept on till it assumes throughout a uniform tint, which is seen by withdrawing it a little from time to time, and letting it cool in the air. One then sees if the matter be sufficiently red. It must be left to cool to judge of this, because it appears black so long as it is hot. The sesquioxide of iron gives a red hue very well, but it is fugitive; for as soon as the oxide of iron enters into fusion, the portion of oxygen which gives it its red tinge quits it, and it becomes black, yellow, or greenish. Thus, to preserve the red color of this oxide in the fire, it must be prevented from vitrifying and giving up its oxygen.

Clouet tried many different substances to procure this fixity for it; alum alone succeeded: the proportions of alum and sulphate of iron may be varied; the more alum that is present, the paler does the color become. Three parts of alum to one of sulphate of iron give a tint which approaches to flesh-color. Alum also renders this hue fixed in a pretty strong fire; this tinge may be employed on the crude enamel; it is much more persistent than purple, but yet not so much so as cobalt-blue. It may be washed to take away the superfluous saline matter; but it may also be employed without being edulcorated; it is even more fixed in this state and finer: it does not require much flux; the flux composed of alum, minium, chloride of sodium, and enamel sand, appears to suit it best. This mixture is compounded in such a manner as to render it sufficiently fusible for its object; from two to three parts of it are mixed with the color. In general, one usually takes three parts of flux to one of color; but this proportion may and ought to vary according to the nature of the hue and the shade desired. The red calcine of iron, quite alone, when it enters into fusion with the glasses, gives a tint which appears black; if this be diffused over a sufficient quantity of glass, it becomes at last a transparent yellow. Thus the tint which is really given by the iron combined with the glasses is a yellow one; but which, being concentrated, becomes so deep that it appears black. In the process indicated above to make the red color, the oxide of iron does not melt, *and this is the essential point;* for if this color is heated till it vitrifies, it becomes black or yellow, and disappears if the coating is thin, and the oxide of iron is in small quantity.

Yellow.—Although this color may be obtained directly, compound yellows are preferred, because they are of surer and easier use than the hue which may be obtained directly from the silver.

The compound yellows are obtained according to the same principles as the red color from iron: to obtain these hues metallic oxides are employed, the complete vitrification of which is prevented by mixing them with other substances, such as refractory earths or metallic oxides difficult of fusion.

The metallic mixtures which constitute the base of the yellows are usually those of lead, minium, white-lead, or litharge; an alkaline antimoniate is also used. The following are the different compositions practised: One part of white oxide of antimony, one of carbonate of lead, or two or three parts—these proportions are very variable—one part of alum, and one part of ammoniacal salt; all these matters are pulverized and mixed well together; then they are put into a vessel on a fire sufficient to sublime and decompose the ammoniacal salt; and the operation is finished when the matter has taken a fine yellow color. The oxide of lead mixed, in small quantity, either with silica or alumina, also with pure oxides of tin, very white, gives likewise yellows; one part of oxide of lead is put to two, three, or four of the other above-mentioned substances.

One may also take for these different yellow compositions, oxide of iron. Different shades of yellow are then obtained, and these may be varied to any desired extent.

The yellows require a little flux; one part or two usually suffice: the saline fluxes do not agree with them, especially those into which nitrate of soda enters.

They must be used with fluxes composed of enamel sand, oxide of lead, and borax, suppressing the chloride of sodium. A yellow may also be drawn directly from oxide of silver—the best way of using which is to employ it pure; then one tints, not paints with it; it is sufficient to put a slight film of it in the place to be colored, and heat the article slightly to give it the hue; the fire must not be too strong; the proper degree will be easily found. When the article has been heated to the point necessary, it is withdrawn from the fire, and the coating of oxide of silver which has been put on, and which should be found reduced to a regulus, is taken off; then the place which it occupies is seen to be tinged a very fine yellow, and having no thickness. It is chiefly on transparent glasses that this process succeeds best; very fine silver filings produce also this effect. The sulphate of silver succeeds very well, pounded with a little water to lay it on evenly. As the pellicle of silver which covers the color has to be removed, it is requisite to avoid fixing the film with fluxes; and it ought, therefore, to be applied after the fusion of the rest, for, as it is very fusible and easily changed, it would deteriorate with the other colors; and as the coating of silver which is reduced must be taken off, the fluxes would fix it, and it could not be removed. This annoyance does not take place with glass, for the silver yellow is laid on the opposite sides from the other colors.

Green Enamel.—It is known that a green color may be produced by a mixture of yellow and blue; but recourse is seldom had to this practice for enamels, as they can be obtained of this color almost always directly with the oxide of copper, or still better with the oxide of chromium, which has the advantage of resisting a strong heat.

There are two oxides of copper—the oxide, which is blue in the state of hydrate, but blackish-brown when dry, and it colors green all the vitreous combinations into which it enters; and the suboxide, of a reddish color, which communicates this to enamels, but it is very fugacious. The oxide requires, at most, one or two proportions of flux, either saline or metallic, to enter into complete fusion; but a much smaller dose is commonly taken, and a little oxide of iron is introduced. To four pounds of frit, for instance, two ounces of oxide of copper and forty-eight grains of sesquioxide of iron are used; and the ordinary measures are pursued for making very homogeneous enamel.

The green produced by the oxide of chromium is much more solid; it is not affected by a powerful fire, but is not always of a fine shade. It generally inclines too much to the dead-leaf yellow, which depends on the degree of oxidation of the chromium.

Red Enamel.—It has just been stated that suboxide of copper affords a fine red color when it can be fixed, a result difficult to obtain on account of its fugitive nature; slight variations of temperature enabling it to absorb more oxygen. The proper point of fusion must be seized, for taking it from the fire whenever the desired hue is brought out; but, when a high temperature has produced a greater degree of oxidation, this may be corrected by adding some combustible deoxidizing matter, as charcoal, tallow, tartar, *et cetera.*

The copper then returns to its minimum of oxidation, and the red color which had vanished reappears. It is possible in this way, and by pushing the heat a little, to accomplish the complete reduction of a part of the oxide; and the particles of metallic copper thereby disseminated in a reddish ground, give this enamel the aspect of the stone called *avanturin.* The easiest and most certain method of procuring suboxide of copper is to boil a solution of equal parts of sugar and sulphate, or rather acetate, of copper, in four parts of water. The sugar takes possession of a portion of the oxygen of the cupreous oxide, and reduces it to the suboxide, when it may be precipitated in the form of a granular powder of a brilliant red. After about two hours of moderate ebullition, the liquid is set aside to settle; the precipitate, decanted off, is washed and exsiccated. The annexed equation represents the decomposition :—

$$\underbrace{48\,Cu\,O}_{\text{Oxide of copper.}} + \underbrace{C_{12}\,H_{12}\,O_{12}}_{\text{Sugar.}} = \underbrace{24\,Cu_2\,O}_{\text{Suboxide of copper.}} + \underbrace{12\,CO_2}_{\text{Carbonic acid.}} + \underbrace{12\,HO}_{\text{Water.}}$$

Pure red oxide, properly employed by itself, furnishes a hue which vies with the finest carmin, and by its means every tint may be obtained from red to orange, by adding a greater or smaller quantity of sesquioxide of iron.

The preparations of gold, and particularly the oxide and purple of Cassius, are likewise employed with advantage to color enamel red, and this composition resists a powerful fire tolerably well.

For some time back, solutions of gold, silver, and platinum have been used with success instead of their oxides; and, in this way, a more intimate mixture may be procured, and, consequently, more homogeneous tints.

Blue Enamel.—This fine color is almost always obtained from the oxide of cobalt or some of its combinations, and these produce it with such intensity that only a very little can be used, lest the shade should pass into black. The cobalt blue is so rich and lively that it predominates in some measure over every other color, and masks many so that they can hardly be perceived; it is also most easily obtained. To bring it out, however, in all its beauty, the other tints must be removed as much as possible, and the cobalt itself should be tolerably pure. This metal is associated in the best known ores with a considerable number of foreign substances, as iron, arsenic, copper, nickel, and sulphur, and it is difficult to separate them completely; but for enamel blues, the oxide of cobalt does not require to be perfectly free from all foreign metals; the iron, nickel, and copper, being most prejudicial, should be carefully eliminated. This object may be most easily attained by dissolving the ore in nitric acid, evaporating the solution to a sirupy consistence, to expel the excess of acid and separate a portion of arsenic. It is now diluted with water, and a solution of carbonate of soda is dropped slowly into it with brisk agitation, till the precipitate, which is at first of a whitish-grey, begins to turn of a rose-red. Whenever this color appears, the whole must be thrown on a filter, and the liquid which passes through must be treated with more of the carbonate of soda, in order to obtain the arseniate of cobalt, which is nearly pure. Since arsenic acid and its derivatives are not capable of communicating color themselves, and as they moreover are volatile, they cannot impair the beauty of the blue, and hence this preparation affords it in great perfection.

Metallic fluxes are not the most suitable for this tint, because they always communicate a tinge of greater or less intensity, which never fails to injure the purity of the blue. Nitrate of soda is a useful addition, as it keeps the oxide at the maximum of oxidation, in which state it produces the richest color.

Black Enamel.—Black enamels are made with binoxide of manganese or protoxide of iron; to which more depth of color is given with a little cobalt. Clay alone melted with about a third of its weight of protoxide of iron, gives, according to CLOUET, a fine black enamel.

Violet Enamel.—The binoxide of manganese, in small quantity by itself, furnishes, with saline or alkaline fluxes, an enamel of a very fine violet hue; and variations of shade are easily had by modifying the proportions of the elements of the colored frit. The great point is to maintain the manganese in the state of binoxide—$Mn\,O_2$—and, consequently, to beware of placing the enamel in contact with any substance attractive of oxygen.

Such are the principal colored enamels hitherto obtained by means of metallic oxides; but since the number of these oxides is increasing every day, it is to be wished that new trials be made with such as have not yet been employed. From such researches some interesting results would unquestionably be derived.

Enamelling of Watch-Dials.—The following is the process for enamelling watch-dials, altered from the *Cyclopedia of Useful Arts:*—

The *dies*, as they are called—consisting of circular plates of brass, of one-twentieth of an inch in thickness—having been moulded to the proper shape, cut to the required size, the feet affixed, *et cetera*, are cleansed in a dilute solution of nitric acid, then washed in clean water with a soft brush and a little white sand, and being quite free from the scales formed on their surfaces during their previous heating with the blowpipe, they are ready for the enamelling.

The tools used for this purpose are—1. An agate mortar and pestle to grind the enamel. 2. A small riveting hammer. 3. A flat spatula, seven-eighths of an inch broad, and a little stronger than those used for paint knives. 4. A spatula of good steel, rather thicker than the last, but of equal breadth; one side of this is flat, and the other a little curved. It is used to spread the hard enamel on the copper. 5. A spatula for spreading the hard enamel on the under side of the copper: this is called the bottom spatula; it is similar to the former, but broader at the end. 6. A quill, cut like a toothpick, for clearing the enamel out of the centre holes of the dials. 7. Two damask napkins for drying the water from the enamels. 8. A small basin with a cover to hold the enamel used for the tops of the dial-plates. 9. A gallipot to contain the enamel for the bottoms. 10. A cylindrical block of wood upon which the copper is fixed, when ready for the laying on of the top enamel. This, for common-sized plates, may be one and a half inch in diameter, and six inches long. Soft wax is fixed at one end of this, so as to form a kind of cap to the block. 11. A box, or tray, to hold the plates when the enamel is spread on them. It may be about sixteen inches long, nine broad, and one and a half deep. 12. A small steel anvil on which to break the enamel. The face is generally about an inch in diameter.

The soft glass enamel is bought by the enameller in cakes, and to prepare it for use it is first broken up with the riveting face of the hammer, any parts colored with red or black streaks being rejected, as they would contaminate the whole. When broken into fragments not larger than small peas, it is carefully ground with water in the agate mortar, and the fine powder, into which it is gradually reduced, is washed away four or five times during the grinding by filling the mortar with clean water, and agitating the enamel with the broad flat spatula, stirring it up from the bottom till the water appears quite milky: the enamel should be allowed to settle to the bottom, and the water poured off. Specks of dirt must be carefully removed, as these will make their appearance on the surface of the dial-plates. The enamel should be reduced to the fineness of fine grain gunpowder; although for some purposes it may be as coarse as maw-seed. After sufficiently grinding, and washing away the flour, the enamel is kept under water in the covered basin until required for use.

For bottoms, the Venetian hard enamel is used; it is broken up with the hammer, and then crushed in a cylindrical iron mortar, with a pestle fitting into it. When pounded until as fine as the glass enamel, it is ground in the agate mortar to an almost impalpable powder; but this enamel is not to be washed, as in this case the flour is of value. It is then kept under water ready for use; for if allowed to get dry after being ground, it must be worked up again in the agate mortar, otherwise it is likely to blister in the fire.

Care must be taken in selecting the Venetian hard enamel, such as is to be used for the faces or tops of dial-plates, so that the color may be pure. To prepare it, it is heated to redness on a piece of platinum in an enameller's muffle, and then suddenly quenched in very clean spring water, which causes it to split up into very small pieces; these are ground up in the agate mortar. The enamel is broken up in this way, to avoid the use of the hammer and steel pestle; because, if a small particle of steel gets into the enamel, it will be productive of mischief. The flour separated during the washings is allowed to subside, and is added to the gallipot with that which is used as bottoms. When the enamel is ground sufficiently fine, it is kept covered with strong nitric acid in a wide-mouthed stoppered glass bottle.

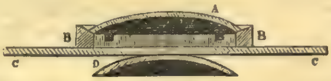
In enamelling with soft glass enamel, a napkin four times doubled is laid on the workboard: the copper is to be held in the left hand with the feet upwards, and a small quantity of the hard enamel for bottoms is taken out of the gallipot on the end of the bottom spatula and spread roughly on the copper, covering it closely up to the feet and centre holes. It is then laid between the folds of the cloth till a little water is absorbed, when the enamel must be extended, as uniformly as possible, with the convex side of the spatula. It must then be more smoothly spread by again drying it with the napkin, and spreading it with the spatula, pressing more lightly as the enamel gets dry. The operation of laying the bottom is then completed by clearing the centre hole with the quill.

A clean napkin is next folded and placed on the board, so as to hang over the edge about three or four inches, a weight being put upon it, to prevent its being dragged down. When the wax upon the laying block has been softened and made of a shape fit to receive the copper, the latter must be placed evenly on, and the feet pressed into the wax, till the enamelled undersurface of the copper nearly touches it. A better method, however, is to place the setting block upon the copper and press it down; for in this way the shape of the copper is preserved, and the upper side secured from the perspiration of the hands, which might cause the enamel to blister. A soft hair-brush, or a hare's foot, is then applied to clean the copper, taking care not to leave any of the hard enamel on the surface or about the edge. A small quantity of the glass enamel is now to be taken upon the end of a flat spatula, and laid upon the copper near the centre hole, being careful not to allow any water to pass through the latter, as that would take away the enamel from the bottom, which could not be replaced without injuring the enamel on the top, the two kinds thus getting mixed, and both being spoiled. When enough of the glass enamel has been put upon the copper, it must be roughly spread, by repeatedly indenting the edge of the flat spatula into the paste, crossing it in all directions till it lies of a uniform thickness. The inequalities thus formed on the surface are reduced by simply tapping the side of the block two or three times with the edge of the spatula, and the side or part of the enamel which is too thick, must be reduced by removing a portion of it to places that appear deficient. This is done by spreading the spatula over the enamel, turning the block round with the fingers and thumb of the left hand, till it lies generally even. The napkin is then again applied, and the surface made smoother by passing the spatula over it in all directions, bearing a little harder on the enamel as it gets drier. As the moisture attracted to the surface by this rubbing and spreading of the enamel would prevent the enamel from lying smoothly, it must be dried again and laid by, passing the spatula lightly over it. In determining the thickness of the enamel, allowance must be made for its more bulky granulated state previous to melting. In enamelling the tops of convex plates, the *shoulder*, which is about one quarter of the distance from the edge to the centre, should be laid somewhat thicker than towards the edge; because the latter being lower than the centre, the enamel, when in a fluid state in the fire, will flow down towards it, and thus produce an inequality of thickness on all parts of the copper. When the copper is covered, it must be carefully removed from the block by gently raising it with the back of the thumb-nail, under the edge, and as near each of the feet as possible. It is then to be placed in the covered tray, and kept free from dust, till wanted for firing.

In hard enamelling, the copper, made chemically clean, is fixed on the laying-block as before, and a coat of soft enamel first laid on, about two-thirds of the thickness applied in soft enamelling. This must be fired till the enamel is melted down to a tolerably smooth surface, and when cold, should any specks of dirt appear, they must be cut out with the point of a square graver whetted to a very obtuse angle. The next operation is to put the plate for a short time into dilute nitric acid, just strong enough to cleanse the scale from the edge of the copper; it must then be washed in clean water, and fixed on the laying-block, the wax being made soft enough to admit the feet without any great pressure. A small quantity of hard enamel, thoroughly purified of the acid by repeated edulcoration, must now be equally spread over the whole surface of the plate, and the corner of a clean napkin laid upon it to absorb a portion of the water. The enamel can then be distributed more evenly over the surface of the plate; when nearly smooth and of uniform thickness, it must be dried again, and the spreading renewed for about ten minutes, rubbing it in every direction till it is compressed as closely as possible.

Firing is the next process, by which the enamel is melted into a uniform vitreous mass on the surface of the copper. A ring is used for supporting the edge of the dial while in the fire, so that the feet may not come in contact with any substance, or they would be loosened. These rings are made of one part pipe-clay and two parts of black-lead. To prevent the adhesion of the enamel to the ring, one part of the ring is made like the frustrum of a very obtuse-angled hollow cone, while the other side forms a plane perpendicular to the sides of the cylindrical parts. The dial, being laid in the hollow side, will just touch it at the part where the copper is exposed, and thus prevent the adhesion of the enamel, especially if this part of the ring be first rubbed with fine whitening. When the dial is placed on the ring, both are set on a flat circular stone or a slab of Stourbridge clay; and as the dial must be kept turning in the fire during the whole time of melting, so as to be equally heated, the slab, with the ring and dial upon it, are set upon a small piece of clay, moulded into the segment of a sphere five inches in diameter. The enamellers call this arrangement a *turner:* it is shown in section in Fig. 444, where A represents a convex dial for a watch without a brass edge; B, the ring; C, the slab or *planch*, and D, the turner.

Fig. 444.



When the furnace is sufficiently heated, the enamelled plates must be laid upon the hearth on a ring of proper size, and there left until the moisture is entirely evaporated. The planch, having been raised to nearly a white heat in the fire, is withdrawn, and the plate and ring set on it, as nearly as possible in the centre, when the whole is to be placed on the turner under the muffle, and kept in motion until the enamel assumes one uniform surface. It must then be withdrawn with the tongs, and another treated in the same way, till the whole day's work is fired: this may vary from three to six dozen plates.

A plate will seldom come out of the fire free from black or green specks. The union of so many small particles will also produce an unpleasant mottled appearance. The specks must be removed with a square graver; and as the centre hole of the copper and also the edge will appear to rise above the surface of the enamel, these are to be carefully filed down, and the plate is then ready for *using off;* that is, rubbing the surface on a gritstone with fine sand and water until the glazed surface is removed, and a uniform rough surface is produced. This removes the mottled appearance, and gives a more equal convexity to the plate. It also takes away the semi-transparent appearance of the enamel, and greatly increases its intense whiteness and beautiful opacity. After the using off, the plates are subjected to the action of a stiff hair-brush and wet sand, then washed in clean water and dried. They are now ready for the finishing fire.

The holes left in picking out the specks are filled up with the finest enamel, almost as fine as flour, and the plate being placed in a proper-sized ring, is set on the iron hearth of the furnace, gradually bringing it nearer the fire until it attains such a heat as will permit it to be placed in the hottest part without danger of cracking. The ring and plate are then lifted upon the planch with the tongs, and kept in motion until a white heat is attained. This being done, it must be taken out of the fire, breathed upon for a few seconds, and immediately returned to the heat: this will bring out a beautiful glass, and a degree of whiteness not hitherto attained by any other means. The proper effect being produced, the plate must be withdrawn and set to cool gradually. If free from specks, the plate is ready for the next process; if specks exist, they can only be removed with the graver—omitting the using off—and the firing must be repeated.

In firing hard enamel dials, the heat must not be so great, and the plate must be taken from the fire as soon as the enamel is found to form a tolerably compact body.

The hours, *et cetera*, are painted on the dial in a soft black enamel prepared for the purpose. It is ground very fine in an agate mortar, and mixed with oil of lavender until sufficiently diluted. A mark is made on the dial to indicate the place of the numeral XII. Then, with the assistance of a division plate and its index, the divisions are slightly traced from the centre with a black-lead pencil. The circular lines which contain the indications of the hours, minutes, *et cetera*, are previously traced with compasses, one point of which is furnished with a cone, and the other with a port-crayon and pencil. When the painting is perfectly dry, the dial is once more fired.

In ornamental enamelling, when the enamel is not intended to cover the whole surface of the plate, it is necessary to form a lodgment for it. The outlines of the design are therefore first drawn upon the plate, and then traced with a graver. The spaces enclosed within the outline of the design must next be deepened by proper tools, equal to the height which would have been given by the ridge or border, had the plate been intended to have been enamelled all over. This deepening is effected with a flat graver, and it must everywhere be of equal depth; for if any shallower portions remain, the enamel falls away, or is so thin in those parts as to show the metal through. The bottom of the lodgments for the enamel must be slightly hatched or roughened with the end of a small riffler file, broken square across, for the purpose of affording a hold to the enamel.

The plate is then thoroughly cleaned, and is next covered with a coat of white enamel laid upon it wetted with water, much skill being required to bring the enamel into contact with the ridges or borders of the design.

In some cases, the design is produced by stamping a steel die upon a gold strip, and the indentations thereby produced are filled up with differently-colored enamels by means of a steel point. This method calls for the display of much skill and taste on the part of the enameller. The enamels are mixed with water or with oil of lavender, according to circumstances; several layers are usually applied, the object being fired after each application.—*Tomlinson.*

Enamelling on Iron and other Metals.—Enamelling of iron for culinary and other utensils, has of late years become a very extensive trade; and the Editor does not wonder at this, for the articles produced are excellent, and will, no doubt, before long come into general use for all ordinary house services. The glazed dishes or basins are also most desirable in the laboratory, and can be employed in nearly all processes of digesting, *et cetera.* Glazed pipes are a great boon, in many instances, as the following proves:—Some time ago, the Editor analysed a sample of water passing through lead pipes in the house of an influential gentleman in the neighborhood of Liverpool. The water was *actually poisoned with the metal.* The family were constantly ill, and *when they left home always became better.* The medical man attending them suspected that there must have been something the matter with the water, and the analysis showed he was right in his surmise. The Editor recommended the lead pipes to be removed, and glazed pipes erected in their stead. The result has been most satisfactory, and no more inconvenience has been experienced.

The enamelling is the patent process of CHARLES HENRY PARIS of France; and his invention, which is largely and most successfully carried out, as far as regards culinary utensils, by Messrs. T. F. GRIFFITHS and COMPANY, an enterprising firm in Birmingham, consists in certain means of coating articles made of wrought-iron with glass or vitreous matter, so as to keep off the atmosphere and other fluids and matters, which would cause an oxidation of the metal. In order that the invention may be most fully comprehended, and readily carried into effect, the Editor proceeds to describe the mode pursued. Articles made of sheet or of wrought iron, whether in the form of vessels, trays, pipes, or otherwise, are first to have their surfaces cleansed, which PARIS prefers to be done by dilute acid, as is well understood, and dried; then a coating of gum-arabic, dissolved in water, is to be applied to the surface by a brush, or otherwise; then by means of a sieve, the fine powder of glass or vitreous matter is to be sifted all over the surfaces. The article is then to be introduced into an oven heated to 212° to 300° Fahr. to be exsiccated; and, when dry, it is to be removed into another chamber, and elevated to a bright red heat till the glass or vitreous matter is melted on the surface, which will readily be seen by looking through a hole in the cover of the recipient. The articles are then to be removed into a close chamber, with a cover to exclude as much as possible the action of the air, till the whole is cooled down. If, on examination, the coating is imperfect, another is to be added in like manner to the first.

The following is the vitreous mixture preferred by the patentee:—One hundred and thirty parts of flint glass reduced to powder, twenty and a half parts of carbonate of soda, and twelve parts of boracic acid. These matters being intimately mixed, are to be placed in a glassmaker's crucible, melted, then drawn off, cooled, reduced to an impalpable powder, which is to be sifted through a fine sieve—say about sixty holes to the inch—and this powder is to be applied in the dry state as before described. It is important, in preparing the glass or vitreous substance, that it should be free from foreign impurities; for this reason, steel stampers are employed for crushing the matters into a powder, and before employing the crucible, PARIS causes it to be coated with glass, by applying gum-water to its inner surface, and then dusting over the powder of glass; and, after the same has been well dried, heating gradually up to the point of fusion of the glass, by which the surface of the crucible will be coated, and will thus, when used, prevent impurities from the crucible getting mixed up with the glass or vitreous mixture. If it be desired that the surfaces of the iron should have colored glass or vitreous matter applied thereto, then, the patentee states, it is first to be coated with the mixture above named, and afterwards a further coating of colored glass is applied to the surfaces, as may be desired. Messrs. GRIFFITHS have succeeded in printing colored designs upon the enamelled wares, and they produce upon a variety of articles a very good effect.

Enamelling on other metals, says BALLANTYNE, is generally performed on plates of gold or of copper, but seldom on silver, as it is apt to occasion flaws in the surface of the enamel. Copper is the metal most generally used for this purpose, coated with the white enamel, on which painting is executed with colors which are melted in the fire, where they take a brightness and lustre like that of glass. This kind of painting is particularly prized for its peculiar brilliancy and vivacity, which is permanent, the force of its hues not being liable to be effaced or sullied by time, as in other painting, and continuing always as fresh as when it came out of the workman's hands. This method of painting is almost entirely confined to miniature; larger works being liable to certain accidents in the operation. The most perfect kind of enamelling is practised on plates of gold, the other metals being less pure. Copper, for instance, sometimes scales with the application; and silver turns the yellow white. To obviate the cracking of the enamel, the plates are generally made a little round or oval, and rather thin. The operation is usually commenced by laying on a couch of white enamel on both sides of the plate, which prevents the metal from swelling and blistering; and this first layer serves for the ground of all the other tints. The next step is to draw out exactly the subject to be painted, with basic sulphate of the sesquioxide of iron, mixed with foreign oil of lavender, marking all parts of the design very lightly with a pencil. After this, the colors —very finely ground, and mixed with the oil, somewhat thick—are to be laid on, attention being given to the mixtures and colors which agree to the different parts of the subject; for which purpose it is necessary to understand painting in miniature.

When the colors are all laid, the painting is to be gently dried over a slow fire to evaporate the oil, and the colors are afterwards melted to incorporate them with the enamel, making the plate red hot in a fire such as enamellers use. Afterwards, the painting may be retouched, and is then to be committed a second time to the fire, and so on till the work be completed.—*Encyclopedia Britannica.*

Enamelling at the Lamp.—The art of the lamp enameller, says URE, is one of the most agreeable and amusing. There is hardly a subject in enamel which may not be executed by the lamp flame in very little time, and more or less perfectly according to the dexterity of the artist, and his acquaintance with the principles of modelling. In working at the lamp, tubes and rods of glass and enamel must be provided of all sizes and colors. The enamelling table is represented in Fig. 445, round which several workmen with their lamps may be placed, while the large double bellows, D, are set a-blowing by a treadle moved with the foot. The flame of the lamp, when thus impelled by a powerful jet of air, acquires surprising intensity. The bent nozzles or tubes, A A A A, are made of glass, and are drawn to points modified to the purpose of the enameller. Fig. 446 shows in perspective the lamp, A, of the enameller standing in its cistern, B; the blowpipe, C, is seen projecting its flame obliquely upwards. The blowpipe is adjustable in an elastic cork, D, which fills up exactly the hole of the table into which it enters. When only one person is to work at the table provided with several lamps, he sits down at the same side with the pedal of the bellows; he takes out the other blowpipes, and plugs the holes in the table with solid corks. The lamp is made of copper or tinplate, the wick of cotton threads, and either tallow or oil may be used. Between the lamp and the workman a small board or sheet of white iron, B, called the screen, is interposed to protect his eyes from the glare of light. The screen

Fig. 445.

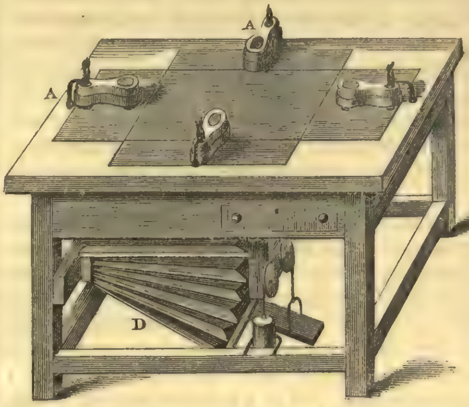
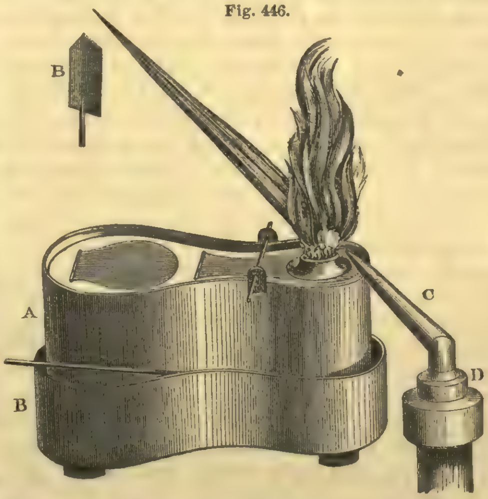


Fig. 446.



is fastened to the table by a wooden stem, and it throws its shadow on his face. The enamelling workshop ought to admit little or no daylight, otherwise the artist, not perceiving his flame distinctly, would be apt to commit mistakes. It is impossible to describe all the manipulations of this ingenious art, over which taste and dexterity so entirely preside. But the following may serve as an example:—Suppose the enameller wishes to make a swan. He takes a tube of white enamel, seals one of its ends hermetically at his lamp, and while the matter is sufficiently hot, he blows on it a minikin flask, resembling the body of the bird; he draws out and gracefully bends the neck; he shapes the head, the beak, and the tail; then, with slender enamel rods of a proper color, he makes the eyes; he next opens up the beak with pointed scissors; he forms the wings and the legs, finally attaching the toes: the bird stands complete. The enameller also makes artificial eyes for human beings, imitating so perfectly the colors of the sound eye of any individual, as to render it difficult to discover that he has a blind and a seeing one.

It is difficult to make large objects at the blowpipe; those which surpass five or six inches become nearly unmanageable by the most expert workmen.—*Ure.*

ETHER.—*Ether*, French; *Æther*, German.—The liquid generally so called—sulphuric ether—is said to have been known to Raymond Lully, who lived in the thirteenth century. The method of making it is described in the dispensatory of Valerius Cordus, from which Conrad Gesner transcribed it into his *Thesaurus Euonymi de Remediis Secretis*, published in 1552, where it is called *Oleum Vitrioli dulce*. Basil Valentine and Paracelsus appear to have been acquainted with ether, though not in a state of purity. Boyle mentions this compound, but he nowhere alludes to it minutely. It was Dr. Frobenius, in 1730, who first drew the attention of chemists to this curious liquor, and he described several of its properties. In his paper it was first called *ether*, for the Germans long distinguished it by the name of *naphtha*.

In modern chemistry, ether is the term given to a class of very light, volatile, inflammable, and fragrant spiritous liquids, obtained by distilling in a retort a mixture of alcohol with almost any acid. Every one modifies the result in a certain degree, whence several varieties of ether are produced. This compound is found in nature in small quantity, not uncombined, but in conjunction with acids, forming neutral ethers. The flavor of the pine-apple, melon, and various other fruits, depends on the presence of these.

Ether.—*Sulphuric Ether—Oxide of Ethyl.* This compound, being the only ether of commercial importance, will be described at some length. It is generally obtained either by distilling a mixture of sulphuric acid and alcohol, or by permitting the latter to dribble into the heated and somewhat weak acid. Phillips gives the following directions for the former process:—To sixteen ounces of sulphuric acid add the same quantity of rectified spirit, and distil over about ten fluid ounces; or continue the operation until the contents of the retort begin to rise, or the residual liquor becomes considerably sulphurous; mix the two products, and if a light and heavy fluid appear, separate them; add potassa to the former, as long as it dissolves; separate the ether from the alkaline solution, and distil about nine-tenths of it, which may be preserved for use. It will have a specific gravity of 0·75. Preparing ether upon a larger scale, it was found that fourteen parts of alcohol—specific gravity 0·820—mixed with the same quantity of sulphuric acid—density 1·80—and submitted to distillation, yielded about eight parts of an impure product—specific gravity 0·770. Seven parts of alcohol were then added to the residuum, and nearly eight parts more of impure ether drawn over. These distillates, when mixed, had a density of about 0·782, and when rectified by distillation over carbonate of potassa, afforded ten parts of ether, having a specific gravity of 0·735, and about three and a half parts of ethereal spirit, which was employed, instead of an equal quantity of alcohol, in the succeeding operation.

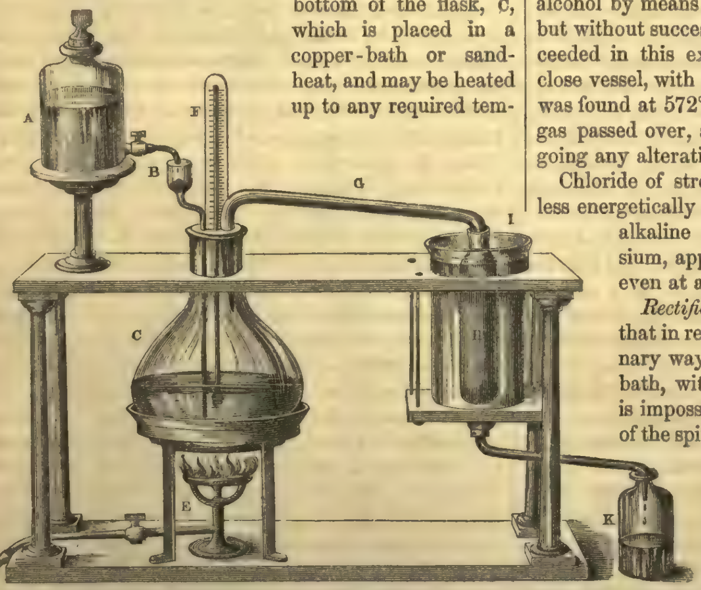
Boullay's method for the production of ether, which is an improvement upon the preceding, is as follows:—Equal parts of sulphuric acid and of alcohol are cautiously mixed in a retort, connected with a tubulated receiver by means of a condensing adapter; the retort is placed in a sand-heat, and the receiver cooled by the proper application of water. An S tube passes air-tight through the tubulure of the retort, the lower end of which is drawn out into a very small or almost capillary opening, and so adjusted as to dip to about two-thirds of the depth of the liquid in the retort; heat is applied till the contents just begin to appear to seethe; the fire is then slackened, or damped, so as to keep up a regular ebullition, and as the apparatus is air-tight, the expansion within is suffered to escape by a siphon tube, which passes through the tubulure of the receiver. When about two parts have passed over, an equal quantity of alcohol is suffered to trickle into the retort by the S tube, so gradually as not to check the boiling, but to compensate for that which distils over. When in this way a quantity of alcohol has been added, equal to that contained in the original mixture, the operation is generally left to itself, and as soon as white vapors and drops of oil appear in the adapter, the fire is withdrawn. The products of this distillation are usually divided into three parts: the first is alcohol with a little ether, which first passes over; the second, and largest, or ethereal portion, is mixed with a sixteenth of its weight of carbonate of potassa, which abstracts water and sulphurous acid, and decomposes any oil of wine—sulphide of ethyryl—that may chance to be contained in it; this mixture is shaken, and when the ether has acquired a sweet and pure odor, it is rectified by slow distillation from a water-bath, till two-thirds of its original bulk are drawn over; the distillate is pure ether. The residue of the rectification is mixed with the last portion of the original distillation, and kept for some days in contact with the alkaline carbonate before used, and a little water and binoxide of manganese are added, so as to oxidize the sulphurous acid; when this is done, the stratum of ether is drawn off and rectified, but it never equals in quality that of the former part of the operation.

It will be observed, that in this process a large additional quantity of alcohol is gradually added, and converted into ether by the original portion of sulphuric acid.

These processes may be conducted on a small scale in glass retorts, with adapters and cooled receivers; but upon the large, a leaden still or alembic is most convenient. The ether apparatus employed at the London Apothecaries' Hall, consists of a leaden still, heated by means of high-pressure steam carried through it in a convoluted leaden pipe; a tube enters the upper part of the still, for the purpose of suffering alcohol gradually to run into the acid in a way which will be presently explained. The still head is of pewter, and is connected by about six feet of tin pipe, with a very capacious condensing apparatus, duly cooled by a current of water; the receivers are of pewter, with glass lids, and have a side tube to connect them with the delivering end of the condensing pipe. In conducting this operation, too much caution cannot be observed in avoiding the proximity of fire and the use of fragile vessels; in all cases in which ether is to be dealt with, these cautions cannot be too strictly enforced, as will be evident when its properties are stated. One of the great advantages in using steam as the source of heat is, that it obviates the necessity of fire in the immediate vicinity of the apparatus.

Brande gives the following arrangement, which answers well for the preparation of ether on a large or small scale. A is the alcohol-holder; it has a grooved stopper, so that, when the stopcock is turned, the spirit may be allowed to drop with any degree of rapidity into the funnel, B, the tube which is elongated, and terminates by a small aperture near the bottom of the flask, C, which is placed in a copper-bath or sand-heat, and may be heated up to any required temperature by the gas-burner, E. F is a thermometer, properly graduated, for showing the temperature of the liquor in the flask. G is a glass tube of a sufficiently capacious bore for the conveyance of vapors from the flask to the condenser, H, which is surrounded by cold water in the vessel, I, and delivers its contents into the receiver, K. In using this apparatus, a mixture of eight parts by weight of concentrated sulphuric acid, and five parts of spirit of wine, of specific gravity 0·834, is introduced into the flask, and heated by means of the lamp till it boils, and attains a temperature of 300°. Alcohol is then suffered to drop in through the long funnel, and by adjusting its quantity on the one hand, and regulating the degree of heat on the other, by the gas-burner, the temperature of 300° is kept as steadily as possible, taking care, at the same time, that the contents of the flask are in rapid ebullition. Under these circumstances, the bulk of this liquor may be maintained uniform for several hours, and every drop of alcohol which falls in is converted into ether and water, the mixed vapors of which pass through the tube, G, into the condenser; and the receiver, K, is ultimately filled with water and ether, the latter floating upon the former.

Fig. 447.



The leading point to be attended to in this operation is the maintaining of a heat of about 300°, with rapid or even violent ebullition. The limits of the ether-producing temperature are between 260° and 310°, and the success of the operation is pretty well insured by the use of sulphuric acid and spirit of wine, in the above proportions, and of the described strength. If more alcohol, or a weaker acid be used, so as to occasion the boiling point to fall below 260°, little else than unchanged alcohol distils over; and if, by the employment of too much sulphuric acid, the boiling point rises up to, or above 320°, in that case *olefiant gas* is generated, together with variable quantities of other products.—*Brande.*

Magnus, some time since, endeavored to etherify alcohol by means of chloride of calcium at 464° Fahr., but without success. **Berthollet** has, however, succeeded in this experiment by acting on alcohol, in a close vessel, with a pure and crystalline chloride; ether was found at 572° Fahr., and at 676° ether and olefiant gas passed over, and this without the chloride undergoing any alteration.

Chloride of strontium produces the same effect, but less energetically; water, chlorides of barium and the alkaline metals, iodide and bromide of potassium, appear to possess no etherifying action, even at a temperature of 712° Fahr.

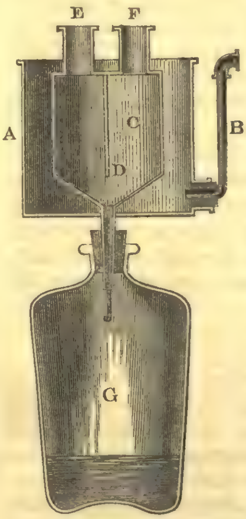
Rectification of Ether.—Dr. **Mohr** states that in rectifying commercial ether in the ordinary way, distilling it by the heat of a water-bath, with a retort and common condenser, it is impossible to effect the complete separation of the spirit, much of which passes over towards the latter part of the process. It is only by frequently ascertaining the specific gravity of the distilled product that the right time for stopping the process can be determined, and even then the ether drawn over will contain some spirit of wine, while the alcohol which remains undistilled will retain some ether. It is true that, by washing the ether with water, the whole of the alcohol may be removed from it; but this is an expensive method of effecting its purification, as the water thus used dissolves ether as well as alcohol, and thus renders another process of rectification necessary, unless it be thought less expensive to sacrifice the ether contained in the washings, than to incur the trouble of recovering it.

This chemist contrived an apparatus, by the use of which ether may be obtained in a state of purity from the unrectified liquor in one operation, while the spirit is, at the same time, left tolerably free from ether.

The principle on which the apparatus is constructed is designated by a term, which may, perhaps, appear somewhat paradoxical, namely, *warm-cooling*. The vapors arising from the impure ether are conducted through a condenser, which is kept constantly at a temperature of 118° Fahr., by the application of warm water. In this vessel, the heat being some degrees higher than the boiling point of ether, yet much lower than that of alcohol, the latter substance is condensed, while the former passes in the state of vapor into a second condenser, which is kept surrounded with cold water, and, when these can be obtained, with ice or snow.

Fig. 448 represents the *ether condenser*, which may be made of sheet-tin, or, preferably, of copper. The cylindrical vessel, A, contains the warm water. It is open at the top, and has a tube, B, inserted through a cork near the bottom, by the turning of which downwards the water may be readily drawn off. A stop-cock might be substituted for this tube, but would be more expensive. The exit pipe of the interior vessel, C, passes through the bottom of the vessel, A. It has two openings at the top to receive the glass or tin tubes, through which the vapors are conveyed to and from this apparatus. C is divided into two departments by the partition, D, so that the vapors pass down one side and up the other, and are thus more completely exposed to the influence of the warm water.

Fig. 448.



The method of conducting the process of rectification with this apparatus will be readily understood.

The crude ether, previously mixed with carbonate of potassa, so as to neutralize any free acid it may contain, is put into a retort, placed in the *steam-funnel*—Fig. 449—or in any other suitable apparatus for applying the heat of boiling water. The beak of the retort is connected by a glass or tin tube, with the opening, E, of the condenser, the delivering tube of which is fixed loosely in the mouth of a bottle, G, which is intended for the reception of the condensed spirit; and at the end of this tube there is a smaller bent tube, inserted by means of a cork, which serves to prevent the ether vapor from passing into the bottle, G, the drop of spirit which is always retained in the end of this tube keeping it closed. To the second opening, F, of the vessel C, a tube is attached, by which the ether vapor is conveyed to an efficient condenser, well supplied with cold water.

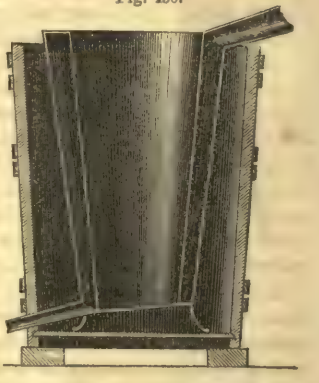
Fig. 449.

The apparatus being thus arranged, the valve of the steam-funnel is opened, so as to admit the steam to the bottom of the retort. At the same time the vessel, A, of the condenser is filled with warm water at a temperature of 118° Fahr., and this temperature is maintained by the addition from time to time of fresh water.

When the distillation commences, ether alone will at first pass over, none of which will be condensed in the first condenser; but when the process has continued for some time, spirit will begin to collect in G, while the quantity of ether passing into the next condenser will be diminished; and, lastly, the distillation of ether will entirely cease, and spirit alone will distil, being liquefied in the first condenser, and collected in G.

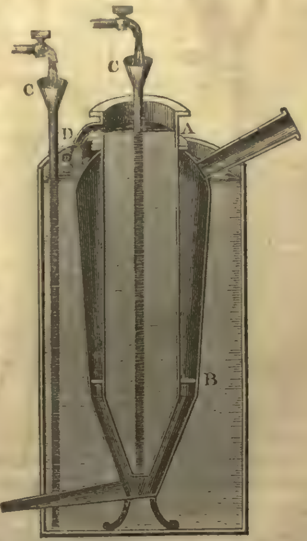
The product obtained by this process has the specific gravity of pure ether. The spirit has a faint smell of aldehyde and ether. It is readily converted into strong spirit or alcohol, by distilling it from carbonate of potassa, or from lime.

Fig. 450.



Gadda's Condensing Apparatus is depicted in Fig. 450. It consists of two conical vessels of metal of unequal size, the smaller being within the other, and the space between them closed at the top and bottom. These are placed in a tub filled with cold water, which comes in contact with the inner and outer surface of the cones, while the space between is occupied by the vapor to be condensed. **GADDA'S** condenser is subject to the objection which applies to the common worm, that it cannot be easily and efficiently cleaned out. To obviate this objection, **MITSCHERLICH** has given to it another form, represented in Fig. 451. In this the inner part of the cone is made cylindrical, and may be taken out, so as to admit of the interior of

Fig. 451.



the apparatus being cleaned. The inner and outer pieces of the cone are united at the top by a joint, A. There is also a perforated ring, B, near the bottom, which keeps the inner cylinder in its proper place. Cold water is supplied by two jets, C, C, and the heated water is carried away by the pipes, D, D. In using this, it is necessary to have a constant supply of cold water, which can be drawn from a reservoir situated above the condenser, unless the tub containing it be large enough to hold the required quantity of water.

Fig. 452.

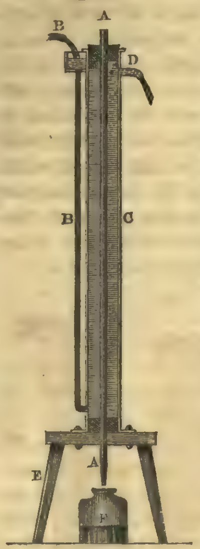
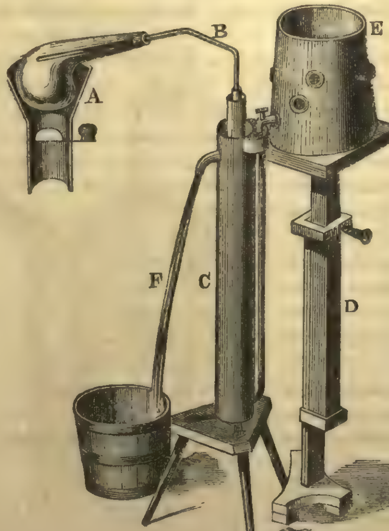


Fig. 452 is the condenser which Dr. **MOHR** is accustomed to employ for ether, *et cetera*. It consists of a glass tube, A, one inch in diameter, and thirty-eight inches in length, which is fitted by means of two perforated corks into the brass cylinder, C, of four inches diameter, and about thirty inches in length. A small tube, B, as shown in the drawing, conveys a stream of cold water to the bottom, and another, D, near the top, carries off the heated water. This apparatus is fixed vertically to a stool, E, under which the receiver, F, is placed.

In Fig. 453 this apparatus is represented in operation: A, the retort, placed in the funnel, with the bent tube, B, connecting it with the condenser, C. The object of this arrangement is to prevent condensation within the conducting tube, which passes some distance into the retort, and to cause none but the most volatile vapors to pass the highest angle of the tube. E is the tub for holding the supply of cold water, which runs in a continuous stream.

Fig. 453.



Composition of Ether.—When the vapor of this body is slowly conducted through a red-hot tube, it is decomposed, and resolved into water, aldehyde, and carbides of hydrogen. According to **LIEBIG**, three equivalents of ether = $C_{12}\,H_{15}\,O_3$, yielding—

3 Eqs. Olefiant gas,..................	$C_6\,H_6$
2 Eqs. Carbide of hydrogen,........	$C_2\,H_4$
1 Eq. Aldehyde,......................	$C_4\,H_4\,O_2$
1 Eq. Water,..........................	$H\,O$
	$C_{12}\,H_{15}\,O_3$

Analysed by passing it over red oxide of copper, ether furnishes the following elementary constituents:—

	At. weight	Theory.	Dumas.	Editor.
4 Eqs. Carbon,....	24	64·87	65·00	64·93
5 Eqs. Hydrogen,.	5	13·51	13·80	13·75
1 Eq. Oxygen,...	8	21·62	21·20	21·32
1 Eq. Ether,.....	37	100·00	100·00	100·00

BERZELIUS for many years regarded ether as the oxide of an *organic metalloid*, or *compound inflammable basis* or *radical*, which he termed ethyl or ethul; from the Greek signifying *principle*. According to this theory, alcohol—see page 49—is a hydrated oxide of ethyl, and ether may be thus represented as an oxide of the same body:—

	At. weight	Per cent.		At. weight.	Per cent.
4 Eqs. Carbon, ..	24	64·86	= 1 Eq. Ethyl,	29	78·[illegible]
5 Eqs. Hydrogen,	5	13·53			
1 Eq. Oxygen, ..	8	21·61	= 1 Eq. Oxygen,	8	22·61
1 Eq. Ether,....	37	100·00	= 1 Eq. {Ox. of ethyl}	37	100·00

The great Swede did not live to see his theory confirmed by the isolation of ethyl; but Dr. **FRANKLAND**, in 1849, obtained it by acting with zinc upon its iodide at a very high temperature. Several products result, but the subjoined equation will point out to the reader how ethyl is produced:—

$$\underbrace{C_4\,H_5\,I}_{\text{Iodide of ethyl.}} + Zn = \underbrace{C_4\,H_5}_{\text{Ethyl.}} + \underbrace{Zn\,I}_{\text{Iodide of zinc.}}$$

It is a colorless, odorless, inflammable gas; burns with a brilliant white flame. Its specific gravity is 2·00394, incondensable to the liquid state at zero, but capable of being converted under pressure of 2·25 atmospheres at 37·5° into a colorless transparent fluid.

Chemists are not yet agreed as to the manner in which the elements in ether are associated, but the Editor is inclined to adopt the Berzelian view, which appears the most simple and satisfactory. Ethyl, $C_4\,H_5$, is represented by E, so that the compounds of this radical may be looked upon as quite analogous to those of potassium, ammonium, *et cetera*. Thus—

Chloride of ethyl,......................	E Cl
Chloride of ammonium,................	Am Cl
Chloride of potassium,.................	K Cl

ETHERIFICATION.—**GRAHAM** remarks, that in the ordinary process of etherizing alcohol by distilling it with sulphuric acid, two distinct chemical changes are usually recognised; namely, first, the formation of sulphovinic acid—bisulphate of oxide of ethyl; and, secondly, the decomposition of the compound named, and liberation of ether. The last step or actual separation of the ether is referred to its evaporation, in the circumstances of the experiment, into an atmosphere of steam and alcohol vapor, assisted by the substitution of water as a base to the sulphuric acid in the place of the ether. The fact that ether is not brought off by a current of air passing through the heated mixture of sulphuric acid and alcohol, is subversive of the last explanation, as it demonstrates that the physical agency of evaporation is insufficient to separate ether. Induced to try whether ether could not be formed without distillation, **GRAHAM** obtained results which appear to modify considerably the views that might otherwise be taken of the nature of the etherizing process. From six experiments which he performed with this view, he arrived at the conclusion that the most direct or normal process for preparing ether appears to be, to expose a mixture of oil of vitriol with from four to eight times its volume of alcohol of eighty-three per cent. to a temperature of 370° for a short time. Owing to the volatility of the alcohol, this must be done under pressure, as in a sealed glass tube. The sulphuric acid then appears to exert an action upon the alcohol, to be compared with that which the same acid exhibits when mixed in small proportion with the essential oils. Oil of turpentine, mixed with one-twentieth its volume of sulphuric acid, undergoes an entire change, being chiefly converted into a mixture of two hydrocarbons, tereben and colophen, one of which has a much higher boiling point and greater vapor density than the oils of turpentine. This carbide of hydrogen does not combine with the acid, but is merely increased in atomic weight and gaseous density without any further derangement of composition, by a remarkable polymerizing action—as it may be termed—of the sulphuric acid. So of the hydrocarbon of alcohol; its density is doubled in ether by the same polymerizing action. Chloride of zinc effects, with alcohol at an elevated temperature, a polymeric catalysis of the latter, of the same character, but in which hydrocarbons are formed of even greater density, and free from oxygen. This view of etherification is only to be considered as an expression of the theory of that process which has long been so ably advocated by **MITSCHERLICH**, who considers the formation of ether as a case of *decomposition by contact*, conceiving that, at a certain temperature—regulated by the dilution of the acid—alcohol, on merely coming into contact with sulphuric acid, is resolved into ether and water. He cites, as parallel cases, the decomposition of oxidised water by gold, silver, and binoxide of manganese, and the action of spongy platinum in determining the combination of certain gases, together with the conversion of sugar into alcohol and carbonic acid by the *contact* of ferment, and of starch into sugar, by means of sulphuric acid.

The formation of sulphovinic acid appears not to be a necessary step in the production of ether; for it has been found that the etherizing proceeded most advantageously with bisulphate of soda, or with sulphuric acid mixed with a large proportion of alcohol and water, which would greatly impede the production of sulphovinic acid. It appears, indeed, that the combination of alcohol with sulphuric acid, in the form of sulphovinic acid, greatly diminishes the tendency of the former to be afterwards etherized; for, when the proportion of oil of vitriol was increased, which would give much sulphovinic acid, the formation of ether rapidly decreased. The previous conversion of alcohol into sulphovinic acid appears, therefore, to be actually prejudicial, and to operate as an obstacle to its subsequent transformation into ether.

The operation of etherizing has attained a kind of technical perfection in the beautiful continuous process now followed. The first mixture of alcohol and sulphuric acid is converted into sulphovinic acid—the sulphate of ether and water—which acid salt appears to be the agent that polymerizes all the alcohol. Bisulphate of soda, with a slight excess of acid, acts upon alcohol in the same manner, and its substitution of the acid sulphate of ether would have a certain interest, in a theoretical point of view, although a change of no practical importance in the preparation of ether.—*Journal of the Chemical Society.*

PROPERTIES OF ETHER.—Ether is a highly volatile, transparent, colorless, limpid liquid, of a peculiar penetrating and agreeable odor, and a pungent and sweetish taste. It is neither acid nor alkaline; has a high refractive power in regard to light; is a non-conductor of electricity; and is sparingly soluble in water, nine volumes of the latter dissolving one of ether. It is dissolved by alcohol in all proportions. It abstracts bichloride of mercury, terchloride of gold, bichloride of platinum, and the sesquichloride of iron from their aqueous solutions. Bromine and iodine are readily soluble in ether; but the solutions, by keeping, undergo decomposition. Sulphur and phosphorus are sparingly dissolved by it. The ethereal solution of the former is luminous in the dark when poured on hot water. It dissolves the volatile oils, most of the fatty and resinous substances, some of the vegetal alkalies, urea, osmazom, gun-cotton—forming collodion—and caoutchouc.

Ether boils at 96° or 97° Fahr., and produces, by its evaporation, a great degree of cold. At the temperature 62·4°, the vapor of ether balances a column of mercury fifteen inches high, or half the weight of the atmosphere. When cooled to minus 24°, it begins to crystallize in brilliant white plates; and at minus 47°, it becomes a white crystalline solid. When its vapor is made to traverse a red-hot porcelain tube, it deposits within it one-half per cent. of charcoal, and there is condensed in the receiver one and two-thirds per cent. of a brown oil, partly in crystalline scales, and partly viscid. The former portion is soluble in alcohol, but the latter only in ether. The remainder of the decomposed ether consists of bicarbide of hydrogen, tetrahydric carbide, carbonic oxide gas, and one per cent. at most of carbonic acid.—*Ure.*

Ether takes fire readily, even at some distance from a flame, and it should not, therefore, be poured from one vessel to another in the neighborhood of a lighted candle. It may be likewise set on fire by the electric spark. It burns entirely away with a bright fuliginous flame. When the vapor of ether is mixed with ten times its volume of oxygen, it ignites with a violent explosion, absorbs six times its bulk of oxygen, and produces four times its volume of carbonic acid gas.

PLANCHE states that ether exposed to air or light, as in bottles which are frequently used, becomes less perfectly volatile, and less capable of dissolving fixed oil, in consequence of the formation of a little acetic acid. The presence of this acid is not at first apparent, because it forms acetic ether, but it gives the ether a peculiar odor, and in time it becomes acid to tests. The best way of preserving ether is to keep it in small well-stopped bottles, or even in sealed tubes, and in a dark place. In some very old ether, which had been often opened, and the boiling point of which was elevated to 130°, **GAY-LUSSAC** found an oily matter, crystallizable, and possessing an ethereal odor.

According to **DÖBEREINER**, ether which has been exposed to the atmosphere contains free nitrogen, the oxygen of the air having combined with the spirit.

MALAGUTI affirms, that when a little ether is introduced into chlorine, the gas is absorbed, and peculiar compounds result. When bubbles of chlorine are passed into ether, they often cause inflammation; and if a small quantity of ether be effused into a large jar of gaseous chlorine, previously warmed, it occasionally happens that a considerable explosion ensues. If the ether be cooled, and chlorine transmitted through it, hydrochloric acid is formed, together with a fluid containing chlorine, which, when saturated with potassa, produces chloride of potassium and acetate of potassa.

SCHÖNBEIN found that a little pure ether put into a bottle filled with oxygen or atmospheric air, and exposed to diffused light, the bottle being occasionally shaken, had partially changed its nature after the lapse of four months. Although producing no action upon blue litmus paper, it discharged the color of a solution of indigo, converted phosphorus when immersed in it into phosphorous acid, eliminated iodine from iodide of potassium, changed protosulphate of iron to basic and sesquisulphates, transformed ferrocyanide into the ferricyanide of potassium, sulphate of lead into sulphite, *et cetera.*

PEREIRA says that the operation of ether upon the system is analogous to that of alcohol, but much more rapid and transient. *Swallowed in moderate doses,* it produces a powerful impression on the mouth, throat, and stomach; allays spasm, and relieves flatulence; but, according to some observers, it augments neither the heat of the body nor the frequency of the pulse. Its first effects on the cerebral functions are those of an excitant, but the subsequent ones are of a depressing nature. *In somewhat larger doses,* it produces intoxication like that caused by alcohol. *In excessive doses,* it occasions nausea, a copious flow of saliva, giddiness, and stupefaction.

The long and habitual use of ether diminishes the effect of this substance over the system, and, therefore, the dose must be proportionally increased. Dr. **CHRISTISON** mentions the case of an old gentleman who consumed sixteen ounces every eight or ten days, and had been in the habit of doing so for many years. Yet, with the exception of an asthma, for which he took the ether, he enjoyed tolerable health. **BUCQUET**, who died of scirrhus of the colon, with inflammation of the stomach and of the intestines generally, imbibed, before his death, a pint of ether daily, to alleviate his excruciating pains.

When the vapor of ether, sufficiently diluted with atmospheric air, is *inhaled,* it causes irritation about the epiglottis, a sensation of fulness in the head, and effects analogous to those caused by the protoxide of nitrogen—laughing gas—moreover, persons peculiarly susceptible of the action of the one, are also powerfully affected by the other. If the air be too strongly impregnated with ether, stupefaction ensues. In one case this state continued, with occasional periods of intermission, for more than thirty hours; for many days the pulse was so much lowered, that considerable fears were entertained for the safety of the patient. In another case, an apoplectic condition, which continued for some hours, was produced. The anæsthetic properties of this vapor are well known. They are similar to those of chloroform, which has almost entirely superseded it. In surgical operations it has been much used for the purpose of destroying sensibility; but preference is now given to chloroform.

The effects of ether on animals have been determined by **ORFILA**, who found that half an ounce, introduced into the stomach of a dog, with the œsophagus tied, caused attempts to vomit, diminished muscular power, produced insensibility, and, in three hours, death. Three drachms and a half injected into the cellular tissue of the thigh, caused death on the fourth day. **JAGER** found that half an ounce of ether acted as a fatal poison to a crane; at the end of forty-eight hours its odor could be readily detected in the body. He made similar experiments on pigeons and ducks. One of the last-mentioned animals took altogether an ounce of ether, yet was not dead at the end of twenty-four hours.—*Pereira.*

GORUP-BESANEZ has published some experiments upon the composition of the blood before and after the inhalation of ether. He invariably found an increase of water, and diminution of blood corpuscles.

Uses.—In medicine, ether is principally valuable as a speedy and powerful agent in spasmodic and painful affections, not dependent on local vascular excitement, and which are accompanied by a pale, cold skin, and a small, feeble pulse. If administered during a paroxysm of spasmodic asthma, it generally gives relief, but has no tendency to prevent the recurrence of attacks. In cramp of the stomach, flatulent colic, *et cetera,* its happy effects are well established. In the latter stages of continued fever, ether is sometimes admissible. **DESBOIS DE ROCHEFORT** administered it successfully in intermittent fevers. Headache, of the kind popularly called nervous, that is, unconnected with vascular excitement, is speedily relieved by ether. In flatulence of the stomach, it may be taken in combination with some aromatic water. As an antidote against sea-sickness, it should be swallowed in a glass of white wine. **DURANDE** recommends a mixture of three parts of ether and two of oil of turpentine as a solvent for biliary calculi. **BOURDIER** employed ether, in infusion of male fern, to expel tape-worm. In faintness and lowness of spirits it is a popular remedy. It has been employed in cases of poisoning by mushrooms and hemlock. The principal external use of ether is to produce cold by its speedy evaporation. Dropped on the forehead, or applied by means of a piece of thin muslin, ether diminishes vascular excitement by the degree of cold occasioned by its rapid volatilization, and is exceedingly efficacious in headache and inflammatory conditions of the brain. In burns and scalds it may be employed as a refrigerant. If its evaporation be stopped or checked, as by covering it with a compress, it acts as a local irritant, causing rubefaction; and if the application is long continued, vesication ensues. It is used with friction as a local stimulant.—*Pereira.*

Ether finds but very limited application in the analysis of inorganic bodies. It serves, in fact, almost exclusively to detect and isolate bromine, and for this purpose the officinal ether of commerce is sufficiently pure and strong. It is used in the preparation of a great many organic bases; the circumstance of its being so volatile is a great recommendation to its employment.

Adulteration.—The ether of commerce is generally unsophisticated, but it is, nevertheless, found much less pure or strong than it should be. The chief adulteration to which ether is liable is by an admixture of alcohol, in which it is soluble in all proportions. The presence of spirit of wine in ether, however, is very easily recognised by pouring a certain quantity of the suspected liquid into a graduated tube, and adding a small quantity of water, which, dissolving the alcohol, produces a much more considerable diminution of volume if the ether contain that body, than when it is pure; of course the mixture should be shaken. It should be recollected that ten parts of water dissolve one of ether, and, consequently, that a diminution in that proportion will always take place, even with pure ether, for which an allowance must be made.—*Normandy.*

Sometimes ether also contains water, which is the case with what is termed *washed ether;* and if ether has been long prepared, it is often slightly acid, and leaves a peculiar odor when rubbed upon the hand. In order to procure from it perfectly *pure ether*, it must be well shaken in a close vessel with about twice its bulk of water, and allowed to separate upon the surface of the mixture; it is then poured off, and a sufficient quantity of well-burned lime added to it, whereby the water which it had acquired by the agitation is abstracted; the mixed ether and lime are then distilled, care being taken to prevent all escape of vapor, and to keep the condensing receivers cold; the first that distils over may be regarded as *pure ether*, free from alcohol and water.—*Brande.*

Having treated at some length of ether, properly so called, it will now be desirable to append the preparation, composition, and properties of a few other substances, partaking of analogous properties, which are daily used, or will sooner or later come into request, for the purposes of the rectifier, perfumer, confectioner, *et cetera.*

ACETIC ETHER.—The preparation, *et cetera*, of this compound has been fully given at page 41. It may be stated here, that, according to PELOUZE, when carbonic acid is passed through an alcoholic solution of acetate of potassa, acetic ether and bicarbonate of potassa are formed.

The annexed equation represents the decomposition:—

$$\underbrace{HO,\ C_4\ H_5\ O}_{\text{Alcohol.}} \ + \ \underbrace{KO,\ C_4\ H_3\ O_3}_{\text{Acetate of potassa.}} \ + \ \underbrace{2\ CO_2}_{\text{Carbonic acid.}}$$

$$= \ \underbrace{C_4\ H_5\ O,\ C_4\ H_3\ O_3}_{\text{Acetic ether.}} \ + \ \underbrace{HO,\ CO_2 + KO,\ CO_2}_{\text{Bicarbonate of potassa.}}$$

This is a curious instance of etherification at common temperatures; the insolubility of the bicarbonate in alcohol is probably concerned in the action.

BUTYRIC ETHER—BUTYRATE OF OXIDE OF ETHYL.—This compound is instantly formed when two parts of butyric acid, two parts of alcohol, and one of sulphuric acid are mixed; it rises to the surface, and is to be washed and rectified over chloride of calcium. It is also very readily obtained by saponifying butter with a concentrated solution of potassa, and dissolving the soap in the smallest requisite quantity of strong alcohol with the assistance of heat, adding a mixture of alcohol and sulphuric acid to this solution until it has a strong acid reaction, and then submitting it to distillation as long as the product has a fruity odor.

The pure ether may be separated from this product by repeated rectification and treatment with chloride of calcium. According to BORNTRAGER, it appears, when prepared in this manner, to consist solely of the ether of butyric acid. This compound, which possesses in so remarkable a degree the pleasant odor of apples, is at present very much used as an aroma in the manufacture of rum.

CAPRIC ETHER—CAPRATE OF THE OXIDE OF ETHYL.—This is formed by passing dry hydrochloric acid gas into a solution of capric acid in alcohol until saturation takes place. Upon the addition of water, the capric ether separates and floats as an oily layer upon the menstruum. It should be well aspersed with water, then dried and digested with fused chloride of calcium. It eliminates in a high degree a pine-apple odor.

CAPROIC ETHER is made precisely in the same way as the above, substituting caproic for capric acid. Caproate of oxide of ethyl is also exceedingly fragrant like pine-apple.

ENANTHIC ETHER.—The presence of a peculiar compound, upon which the fragrancy and persistent odor of certain wines depends, has already been adverted to at page 105. It is obtained by agitating the oil derived from brandy or from grain spirit—*weinfuselöl*—which is a mixture of enanthic acid and enanthic ether, with a solution of carbonate of soda, till the free acid is neutralized; heat is then applied, and the enanthic ether separates upon the surface, and may be dehydrated by chloride of calcium. It is an oily liquid, of a strong, and even intoxicating vinous odor, soluble in ether and in alcohol, but not in water. It is not decomposed by carbonate of potassa. The specific gravity of enanthic ether is 0·862, and the density of its vapor = 10·5.—*Brande.*

HYDROCHLORIC ETHER—CHLORIDE OF ETHYL.—*Sweet or dulcified spirit of salt* was a favorite preparation with the old chemists. They conceived it to possess some peculiar solvent powers in regard to the salts of gold. It was also used in medicine. It was prepared in various ways; either by distilling a mixture of alcohol and hydrochloric acid, or of chloride of sodium, sulphuric acid, and alcohol.

Chloride of Ethyl, remarks BRANDE, may be obtained by subjecting to careful distillation a concentrated solution of hydrochloric acid gas in alcohol; or a mixture of one part of alcohol, one of sulphuric acid, and two of fused and finely-powdered chloride of sodium; or a mixture of alcohol with chloride of antimony, or chloride of tin. In all these cases, chloride of ethyl passes over; it should first be transmitted into warm water, by which its adhering acid and alcohol are abstracted, and its vapor may then be condensed by conducting it through a cold tube, and receiving it in a bottle surrounded by ice and salt. BOULLAY'S process for its preparation, as given in BRANDE'S *Manual of Chemistry*, is as follows:—Absolute alcohol is saturated with dry hydrochloric acid gas, and the resulting liquor introduced into a flask connected with two Woulfe's bottles, the first of which contains water at about 80°, while the second is immersed in a mixture of ice and salt. On applying heat to the flask, the vapor of alcohol and hydrochloric acid are retained in the first bottle whilst the vapor of the ether passes over, and is condensed in the second.

According to BRANDE, chloride of ethyl is a limpid, colorless liquid, of a peculiar penetrating odor, and a sweetish acrid flavor. It is neutral. Its specific gravity is 0·874 at 420°. It boils at 60°. The density of its vapor is 2·219. When cooled down to 10°, it crystallizes in cubes. It is soluble in about fifty parts of water, but in all proportions in alcohol and ether proper. It dissolves sulphur and phosphorus, and the fat and volatile oils. Its components are—

	At. weight.	Theory.	Dumas.
4 Eqs. Carbon,	24	36·9	37·73
5 Eqs. Hydrogen,	5	7.7	7·70
1 Eq. Chlorine,	36	55.4	54·57
1 Eq. Chloride of ethyl,	65	100·0	100 00

or,

	At. weight.	Dumas.
1 Eq. Ethyl,	29	35·43
1 Eq. Chlorine,	36	54·57
1 Eq. Chloride of ethyl,	65	100·00

Chloride of ethyl is a highly diffusible stimulant like the other ethers, but is rarely employed alone, though it has been used as an antispasmodic. It is usually prepared by dissolving hydrochloric ether in an equal volume of rectified spirit. The action of this compound seems to be similar to that of nitric ether. A scruple of it thrown into the veins of a buck augmented the renal secretion. An ounce and a half injected into the jugular vein of a dog coagulated the blood, caused difficulty of breathing, and death. It has been used in dyspeptic affections connected with hepatic obstructions. In hectic fever, BERENDS found its continued use beneficial.—*Pereira.*

NITRIC ETHER—NITRATE OF OXIDE OF ETHYL.—The mutual action of nitric acid and alcohol had been always found to be so violent that the production of this ether was believed impossible, until MILLON remarked that the intense action is due to the nitrous acid which ordinary nitric acid always contains, and that by using absolutely pure nitric acid, and preventing the formation of nitrous acid, the real nitrate of ether can be obtained with facility. To prevent the production of nitrous acid, he employs urea, which is immediately decomposed by and destroys nitrous acid. When two ounces of absolute alcohol and one ounce of strong nitric acid are mixed, and twenty grains of urea are added, the reaction is very moderate; and after some time a very heavy oily liquid begins to separate, and is increased in quantity by the addition of water. This is true *nitric ether*. It is colorless, has a specific gravity of 1·112, and boils at 184°. Its odor and taste are agreeable, and the alkalies decompose it into alcohol and nitric acid.—*Kane.*

MILLON gives the following as its composition:—

	At weight.	Theory.	Millon.
4 Eqs. Carbon,	24	26·4	26·50
5 Eqs. Hydrogen,	5	5·5	5·72
6 Eqs. Oxygen,	48	52·7	52·52
1 Eq. Nitrogen,	14	15·4	15·26
1 Eq. Nitric ether,	91	100.0	100·00

=

1 Eq. Ether,	37	40·8
1 Eq. Nitric acid,	54	59·0
1 Eq. Nitric ether,	91	100·0

This ether, dissolved in alcohol or distilled with it, is largely used in medicine.

Spirit of nitric ether, as the solution or distillate is termed, is a colorless, limpid liquor, having a fragrant ethereal odor, somewhat analogous to that of ripe apples, and a pungent aromatic taste. It is very volatile, producing much cold by its evaporation. It is very inflammable, and burns with a whitish flame. It is principally distinguished by its peculiar odor, its inflammability, its lightness, and its miscibility with water. The spirit of nitric ether of the shops usually strikes a deep olive color with the protosulphate of iron, thereby indicating the presence of binoxide or an acid of nitrogen; and produces, with tincture of guaiacum, a blue tint, which passes through various shades of green: this last effect depends on the presence of an acid of nitrogen. These effects are not invariably produced; for in some spirit of nitric ether which PEREIRA had for several years they did not take place. According to this pharmacologist, it is employed as a diuretic in some disorders of children, and in mild dropsical complaints, as in the anasarca which follows scarlatina. It is given in conjunction with squills, acetate or nitrate of potassa, or foxglove. As a refrigerant and diaphoretic, it is used in febrile complaints, in combination with the acetate of ammonia and emetic tartar—tartrate of antimony and potassa. As a carminative, it is frequently useful in relieving flatulence and allaying nausea. From its volatility, it may be applied to produce cold by its evaporation. Spirit-dealers employ it as a flavoring ingredient.

NITROUS ETHER—NITRITE OF THE OXIDE OF ETHYL.—The process ordinarily used for preparing nitrous ether is that of THENARD; and consists in treating alcohol directly with nitric acid of commerce. For this operation, the ordinary distillatory apparatus is employed, the receiver of which is surrounded by a refrigerant mixture, and the tubulure is furnished with a safety tube communicating with three Woulfe's receivers, half filled with a saturated solution of chloride of sodium, and surrounded by a refrigerant mixture.

The capacity of the still should be equal at least to five times the bulk of the mixture of alcohol and nitric acid employed; and, notwithstanding all the care which may be observed in heating the still, the mass intumesces so much at a certain period, that the fire is always obliged to be suddenly withdrawn, and, for the greatest part of the time, wet cloths have to be placed on the still head, so violent is the reaction. These various manœuvres are far from being without risk, as the retort may sometimes blow up.

The danger in which the operator is placed is doubtless a very serious inconvenience; but it is not the only one; indeed, by proceeding thus, only about one-fifth of the alcohol employed is converted into nitrous ether; since there is produced, at the same time as the nitrous ether, water, acetic, formic, and carbonic acids, and aldehyde; there are also formed binoxide and protoxide of nitrogen, and nitrogen itself may be found in the free state, so energetic is the decomposition. Finally, a small quantity of undecomposed nitric acid passes into the receiver.

Throughout this molecular movement, a certain amount of nitric acid is reduced to the state of nitrous acid, which, combining in the nascent state with ether, gives nitrous ether, but in very small quantity in proportion to the alcohol employed.

Grosourdi considers that electricity performs the principal part in this reaction, at the moment when the various molecules enter into new combinations, neutralize their contrary electricities, and develop throughout an enormous amount of caloric which, by its presence, causes all the danger of the experiment.

From these considerations, he thought it necessary to seek for a process, which, by avoiding the too violent action of nitric acid or alcohol, should not only render the operation free from danger, but also convert into nitric ether, if not the whole of the alcohol employed, at least the greater part of it.

With this view, nitric acid was made to act in the nascent state on alcohol, or rather on the ether, also in the nascent state; but this process not succeeding to his entire satisfaction, he put nitrous acid in the nascent state in contact with ether, also in the same state, since the alcohol employed had been previously treated with concentrated sulphuric acid; by this means the object proposed was attained.

Nitrite of potassa is prepared by deflagrating in a Hessian crucible one hundred parts of commercial nitrate of potassa, previously reduced to very fine powder and intimately mixed with 12·07 parts of lamp-black, which may be regarded as almost pure carbon. When the deflagration is concluded, the crucible is covered, removed from the fire and allowed to cool; after cooling, it contains a very white and very hard mass; this is nitrite of potassa with traces of carbonate and subsilicate of the same base. These two salts will be in so much the smaller proportion as the mass has been less powerfully heated, and especially as the deflagration has been more rapid.

The following equation will explain the reaction; the carbonate and the subsilicate of potassa being omitted, as their presence is only accidental:—

$$\underbrace{2\,C}_{\text{Carbon.}} + \underbrace{KO, NO_5}_{\text{Nitrate of potassa.}} = \underbrace{KO, NO_3}_{\text{Nitrite of potassa.}} + \underbrace{2\,CO}_{\text{Carbonic oxide.}}$$

Before entering into the details of this new process, Grosourdi states the following facts:—

Nitrite of potassa, pulverized and put into a test tube, with a sufficient quantity of alcohol, at 88·06 of alcoholometer, to form over it a layer of a few lines in thickness, no longer disengages nitrous acid, which is so easily recognised by its odor and color when treated with sulphuric acid—a reaction which always takes place when this salt is treated with sulphuric acid, either with or without water, and which is a characteristic reaction of this kind of salt. It would be necessary, therefore, before employing the sulphuric acid, to expel the alcohol.

The reaction of the nitrites, treated with sulphuric acid when protosulphate of iron is present, is also modified by the liquids containing a certain quantity of alcohol. Indeed, the brown coloration appears but slowly, and forms an areola round the crystals of the salt of iron, but it disappears immediately on agitating the menstruum.

To prepare nitrous ether, he put into a glass retort 17·50 parts of alcohol of 85°, twenty-five of nitrite of potassa, and twelve of sulphuric acid, and by this means converted into nitrous ether almost all the real alcohol employed, as is proved by the annexed equation:—

$$\underbrace{KO, NO_3}_{\text{Nitrite of potassa.}} + \underbrace{HO, SO_3}_{\text{Sulphuric acid.}} + \underbrace{HO, C_4\,H_5\,O}_{\text{Alcohol.}} =$$

$$\underbrace{C_4\,H_5\,O, NO_3}_{\text{Nitrous ether.}} + \underbrace{KO, SO_3}_{\text{Sulphate of potassa.}} + \underbrace{2\,HO}_{\text{Water.}}$$

The apparatus is composed of a tubulated retort, the tubulure of which is closed with an accurately-fitted stopper; it is made to communicate with a tubulated receiver by means of two adapters, arranged end to end; to the tubulure is fixed, instead of the ordinary straight tube, one with two bends; the longer of these, at least twenty-three and a half inches in length, dips into a deep glass filled with mercury. This is simply the ordinary distillatory apparatus, slightly modified.

Care must be taken that all the corks which unite the different pieces be not only hermetically sealed, but also that they be tied round with string, and then covered with a layer of luting. The retort is placed in an empty water-bath, into which the water is only introduced when necessary to raise the temperature; and the receiver is put into a vessel containing cold water, which is continually renewed, so as to keep it almost entirely covered; if it can be surrounded with ice or even with a refrigerant mixture, so much the better; but this is not indispensable, for very cold water has always answered the purpose. The apparatus thus arranged is suitably maintained and fixed by means of supports.

The object of the tube dipping in mercury is twofold; first, to prevent the loss of a certain quantity of ether, which, without this precaution, would make its way into the atmosphere; secondly, to produce pressure, and especially to facilitate condensation.

This done, nitrite of potassa in fine powder is introduced into the retort; then half the alcohol employed is added, and the whole well mixed. The sulphuric acid previously mixed with the other half of the alcohol is now poured through a funnel by small portions at a time, taking care to agitate frequently; when this mixture has become quite cold, only a few bubbles of carbonic acid are disengaged, and no nitrous acid. The liquid remains perfectly colorless, and there is no apparent reaction, nor even any appreciable elevation of temperature.

The retort is then closed, and the whole is left to itself at the ordinary temperature, which should not exceed 50°. When the experiment has been made, and several times repeated, care must be taken to agitate the mixture every seven or eight hours, in order to change the points of contact, and especially to facilitate the reaction.

At the end of eight hours' contact, when the retort is opened for the first time, the peculiar odor of the nitrous ether is already slightly appreciable; but in twenty-four hours, when it is again opened for the purpose of stirring the mixture, a powerful odor of apples is perceived.

After forty-eight hours' contact, pour into the bath water at the temperature of 86°, and maintain it at this point; then the nitrous ether soon distils over, and passes into the receiver.

The operation should be conducted very slowly, without raising the temperature of the water-bath beyond 95°. When there is no more liquid in the retort, and the mass appears semi-solid, remove, by means of a siphon, all the liquid condensed in the receiver; then pour into the retort sufficient water at 113° to cover the saline mass.

This done, mix the whole well by means of the agitator; then continue the distillation, raising the temperature of the sand-bath to 113° and 122°; and by operating thus, there is obtained in the receiver a further quantity of nitrous ether, but which is not quite so pure as the first portions. The liquid remaining in the receivers, and which by cooling deposits crystals of sulphate of potassa, is yellow, and has a very powerful nitrous odor, partaking also of that of slightly rancid fatty matters. Its color and smell are due in a great measure to the presence of a peculiar substance which will be presently noticed.

From what has just been stated, it is evident that by this process the operator is exposed to no danger, since he is always able to govern the operation, which must be conducted slowly if he wishes to obtain a good product. As to the greater production of nitrous ether, this may easily be ascertained by weighing, after rectification, the ether resulting, and it will be found that it weighs more than two-thirds of the alcohol employed.

Thus obtained, the nitrous ether which has been removed from the receiver by means of a siphon, scarcely reddens litmus paper, and, most frequently, requires only a simple distillation at 68°, or 71° at most, if the operation has been properly conducted, to be pure.

When purified, this nitrous ether is perfectly colorless, and gives out a sweet odor of apples; it does not redden litmus paper the moment it is dipped in it, but when once this paper is impregnated, it soon becomes red by exposure to the air—at first gradually, and afterwards more rapidly, and ultimately the same as with the powerful acids. This reaction is the result of the decomposition of nitrous ether under the influence of the oxygen of the air, which, doubtless, makes the nitrous ether pass unto the state of nitric acid, by setting the ether at liberty. This body should consequently be kept in well-stopped flasks, so as to avoid all contact with the atmosphere.

As to the ethereal liquid obtained after having added water to the retort, it is powerfully acid, and often of a yellowish color, especially if the temperature has been raised too high. For its purification, it must be treated in a stoppered flask with one-tenth of its weight of pure carbonate of potassa, in very fine powder, taking care to agitate the flask very frequently, so as to multiply the points of contact, and each time to allow the carbonic acid disengaged during the agitation to escape. After half an hour's contact, or more, if the liquid is still acid to litmus paper, it is distilled as directed above, which should be repeated several times, if necessary; thus a further quantity of perfectly pure nitrous ether is obtained.

In all these cases, the flask should never be filled beyond two-thirds of its capacity.

This ether is perfectly colorless, although some chemists assign to it a yellow tinge; but when in this state, it is not pure, holding in solution a peculiar substance, which, when isolated, is a reddish, yellow oleaginous body, having a peculiar smell resembling that of fatty matters left for a certain time to the action of damp air. It is an odor like that of rancid matter mixed with something aromatic; and is so persistent, that when the fingers touch it, they remain for a long time impregnated. It is very soluble in the ethers and in alcohol.

GROSOURDI procured this substance by treating with ether the residue resulting from the spontaneous evaporation in the sun, under a bell glass containing quicklime, of the yellowish liquid which contained the crystals of sulphate of potassa, after the preparation of the nitrous ether; or else by heating in the same manner the residue of the purification of this same ether, when it was obtained colored, owing to too great heat in its preparation. Then the ethereal liquid resulting from it, left to spontaneous evaporation, as has been already stated with regard to the yellow liquid from which the sulphate of potassa is deposited, left this body in the pure state at the bottom of the capsule, the ether being entirely disengaged.

GROSOURDI'S process for the fabrication of nitrous ether is certainly to be preferred to that of THENARD, inasmuch as it is free from danger, and furnishes a larger quantity of purer ether. When nitrite of potassa cannot be obtained, the following menstruum may be used:—

Nitrate of potassa,	57·48	parts.
Commercial sulphuric acid at 60°,	25·89	"
Alcohol at 86°, of the alcoholometer 116°.		

The following represents the change :—

$$\underbrace{2\,(HO, C_4 H_5 O)}_{\text{Alcohol.}} + \underbrace{KO, NO_5}_{\text{Nitrate of potassa.}} + \underbrace{HO, SO_3}_{\text{Sulphuric acid.}} =$$

$$\underbrace{C_4 H_5 O, NO_3}_{\text{Nitrous ether.}} + \underbrace{KO, SO_3}_{\text{Sulphate of potassa.}} + \underbrace{5\,HO}_{\text{Water.}} +$$

$$\underbrace{C_3 H_3}_{\text{Carbide of hydroden.}} + \underbrace{CO}_{\text{Carbonic oxide.}}$$

From this it may be readily seen, that the reaction is much more complicated than in the former process; indeed, an equivalent of alcohol is lost to the etherization, since, in being converted into nitrous acid, under the influence of the nitric acid, it is reduced into water, carbonic acid, and the carbide of hydrogen, which constitutes the oleaginous substance mentioned.

After having mixed together, with the proper precautions as to the elevation of temperature, the alcohol and sulphuric acid, the mixture is poured, after complete cooling, into the tubulated retort, the apparatus having been previously arranged as above stated. This done, the nitrate of potassa in fine powder is introduced in small quantities at a time; care is taken, at the same time, to agitate the mixture well with the whalebone agitator, in order to multiply the points of contact; the still is then closed, and the whole is left to itself for three days at a temperature of 59°; the mixture is then carefully agitated every seven or eight hours.

At the moment when the nitrate of potassa is put into the mixture of alcohol and sulphuric acid, there is neither elevation of temperature nor any apparent reaction; but when the mixture is agitated for the first time, at the end of seven or eight hours' contact, a slight odor of nitrous ether is perceived, which becomes more and more powerful, so that at the end of forty-eight hours it is very perceptible when the retort is opened. At this moment, by the agitation occasioned in the mixture by this operation, a multitude of small bubbles of carbonic acid are disengaged, so that the mass appears to be effervescent; this phenomenon is also apparent at the end of twenty-four hours' contact, but in a much less degree. Then the liquor containing the saline mass is colored yellow.

At the end of from sixty to seventy-two hours, water at the temperature of 77° to 80° is put into the bath, which is maintained at this point, and nitrous ether is soon observed to distil over into the receiver in which some has already condensed. The operation should be very slowly conducted to obtain a good product. Towards the termination of the experiment—when the greater part of the liquid contained in the retort has passed into the receiver—the temperature of the bath may be raised to 122°, but the liquid condensed in the receiver must be removed.

The operation being completed—that is to say, when no more nitrous ether comes over—one proceeds to purification and rectification, as already pointed out in speaking of the same operation for nitrous ether obtained by means of nitrite of potassa.

During the whole time that these processes are being performed, the bulk of the mixture is not sensibly augmented; consequently, the operator is not exposed to any danger, and has the greatest facility in conducting the operation, which, for the chief part of the time, does not even require his presence.

Any of the nitrates may be employed, but preference is given to that of potassa, as being the most economical and most abundant in commerce. As to the nitrites, they may all be submitted to that of potassa, but those in which the base and acid have only a feeble affinity for each other would ill fulfil the object.—*Journal de Chimie Médicale.*

PELARGONIC ETHER is procured in a similar manner to the other fatty compounds; that is, by passing hydrochloric acid gas through a solution of pelargonic acid in alcohol. It is an oily liquid, possessing a very peculiar odor, and boiling at 240°. According to FRANKLAND, it is to this that whisky owes its flavor; and GREGORY states that it is now manufactured by a secret process, and vended at a high price, for the purpose of imparting to new whisky the fragrance of old. The occurrence of pelargonic acid in whisky shows that the acid is derived from sugar.

The Editor appends the formulæ representing the different ethers described :—

Name.	Formula.
Acetic ether, ...	$C_4 H_5 O, C_4 H_3 O_3$.
Butyric ether, ...	$C_4 H_5 O, C_8 H_7 O_3$.
Capric ether, ...	$C_4 H_5 O, C_{20} H_{19} O_3$.
Caproic ether, ...	$C_4 H_5 O, C_{12} H_{11} O_3$.
Enanthic ether, ...	$C_4 H_5 O, C_{14} H_{13} O_2$.
Hydrochloric ether, ...	$C_4 H_5 Cl$.
Nitric ether, ...	$C_4 H_5 O, N O_5$.
Nitrous ether, ...	$C_4 H_5 O, N O_3$.
Pelargonic ether, ...	$C_4 H_5 O, C_{18} H_{17} O$.

END OF VOLUME ONE.

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v.1 arts and manufactures

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